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Network management practices: an empirical analysis

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Monterey, California

THESIS

**NETWORK MANAGEMENT PRACTICES:
AN EMPIRICAL ANALYSIS**

by

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September, 1997

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NETWORK MANAGEMENT PRACTICES: AN EMPIRICAL ANALYSIS

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September, 1997

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As organizations continue migrating mission critical applications and business processes to distributed computing environments, network utilization and the number of bandwidth-intensive applications will continue increasing. Costly network infrastructure upgrades are forcing organizations to explore alternative management methodologies for addressing bandwidth congestion control. In an era of stagnant budgets and increasing IT requirements, DOD is no exception. The enactment of the Information Technology Management Reform Act of 1996 mandates investigating cost-effective ways of managing 21st Century network resources.

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And finally, we thank God for all that He has accomplished through us, including this research project. "I am the vine, you are the branches. He who abides in Me, and I in him, he it is that bears much fruit, for apart from Me you can do nothing." [John 15:5]

I. INTRODUCTION

"The government obligated more than $23.5 billion toward information technology products and services in fiscal year 1994–about five percent of the government's total discretionary spending. Yet the impact of this spending on agency operations and service delivery has been mixed at best" (GAO, 1996a). According to the Government Accounting Office (GAO), the US Defense budget plan will remain fairly constant during the next five years, including a consistent average of 5.9 billion dollars budgeted for central command, control, and communications in an overall defense budget of 108 billion dollars (GAO, 1996b). In an era following dissatisfaction with the Department of Defense's (DOD) management of information technology (IT), evidenced by passage of the Information Technology Reform Act (ITMRA), there will surely be funding obstacles for military organizations who plan to further develop their IT capabilities.

The constant DOD funding levels and the ITMRA's attempt to run government agencies as businesses are at odds with each other. According to Morgan Stanley in Figure 1, the amount of IT capital investment is rising compared to other types of capital investment (1997). Assuming that this trend is consistent with most corporate businesses,

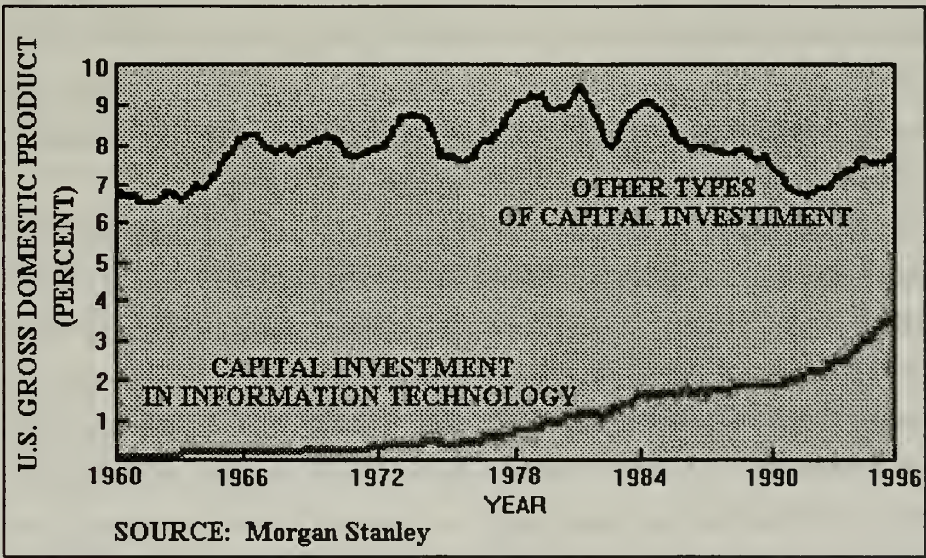

Figure 1. Capital Investment Trends (Gibbs, 1997).

it is not hard to see where DOD's IT efforts may continue to flounder. "IT expenditure on capital equipment is estimated to be the largest share of total US business outlays – up from just 20 percent in 1980 to 45 percent in 1993" (US NII Virtual Library, 1997).

There is an overwhelming need for finding cost-effective ways to manage these DOD IT assets, including the thousands of miles of defense networks–while increasing their effectiveness and efficiency during a time of stagnant funding and increasing demands.

Defense computing networks are not the only networks needing good management.

> Businesses have flocked to the Internet, deployed intranets at a dizzying rate and pushed out massive multimedia applications to desktop users. Amid this flurry of activity, many businesses failed to anticipate the network congestion these new applications can cause (Henderson, 1997).

Organizations outside the DOD are also feeling the effects of increased network usage and diminishing monetary resources. “In fact, Strategic Networks estimates that overall network traffic is rising 40 percent a year, while net managers’ budgets are climbing a mere 5 percent annually” (Lippis, 1997). Recent phenomenon such as "right-sizing" and business process re-engineering (BPR) have illuminated the commercial organizations’ need to better manage their resources. One such computing resource that has, until recently, been overlooked and taken for granted is network bandwidth (the number of bits that pass through a network element per second in Kbps or Mbps). Increased network activity, bandwidth-intensive applications, and larger geographic boundaries have forced organizations to find ways to achieve more traffic throughput on their networks. There have been recent measurable increases in maximizing digital bandwidth using coding schemes, compression technology, faster transmission media, switching technology, and ultra high frequency transmission bands.

Despite the advances in network IT, organizations are still struggling to keep up with the growth of network usage. They have collectively spent trillions of dollars in upgrading networks–in creating larger bandwidth "pipes"–without looking for ways to more effectively manage or use the bandwidth they already have. Unlike typical military Radio Frequency (RF) communication networks (radio or satellite) which prioritize messages and bandwidth use, most organizations do not evaluate or prioritize digital message content to determine bandwidth usage on their distributed computing networks.

Instead of funneling monetary resources into creating more bandwidth "pipe," network managers must find methodologies to optimize use of existing network resources, including those that have been plentiful and have been taken for granted. One emerging management technology meets this requirement–transmission prioritization (policy-based traffic management) technique. An additional network management technology that has

existed for decades in the mainframe computing environment, but has not been widely adapted to the distributed computing environment, is chargeback for computing resources. This thesis will examine these emerging technologies and their uses in academic, military, and business sector organizations, and apply them to the DOD.

A. PURPOSE

The objective of this research is to review current bandwidth management techniques that utilize prioritization schemes and charging mechanisms in a distributed computing environment, focusing on military, academic, and business sector networks. The research will test our descriptive hypothesis that the majority of academic, military, and commercial organizations use prioritization (policy-based traffic management) and/or chargeback policies to manage their distributed computing networks. In addition, this thesis will attempt to assess the future impact of these emerging technologies on DOD 21st century networks. It will review current technologies and provide an assessment for their future use.

B. RESEARCH QUESTIONS

1) What are the historical/traditional economic decision variables/parameters used to define network management?

2) What variables are required to manage current distributed computing networks?

3) What is the effect of additional/differing decision variables on network management methodologies?

4) What are the current network management practices of network administrators in academic institutions, specifically in terms of prioritization mechanisms and charging schemes?

5) What are the current network management practices of network administrators in military institutions, specifically in terms of prioritization mechanisms and charging schemes?

6) What are the current network management practices of network administrators in the business sector, specifically in terms of prioritization mechanisms and charging schemes?

7) What would be an appropriate way for DOD network managers to administer their bandwidth and prioritize network usage?

C. THESIS OUTLINE

Chapter I identifies the fundamental logic behind the need for research into prioritization and chargeback mechanisms as methods of network management control. Chapter II provides a detailed background of network management concepts. Section A defines basic terminology, functional areas, and tasks included in the Open Systems Interconnection (OSI) network management model. Section B provides a breakdown of computing resources and a comparison of mainframe computing resources to network computing resources. Section C examines network resource management methodologies, including traditional infrastructure management, chargeback methodologies, and prioritization methodologies.

Chapter III explains the research methodology used in this descriptive study. Included are identification of the sample chosen, the survey instrument used, and the analysis strategy employed. The research findings are presented in Chapter IV. Findings include: survey instrument response rate, survey variable frequencies, descriptive hypothesis and correlation test results.

The conclusions and recommendation are presented in Chapter V. The results of descriptive hypothesis testing as well as the future of chargeback and prioritization as means of management control methodologies are addressed. It also includes recommendations for application of these mechanisms to DOD, as well as suggested further studies. Appendices include the survey instrument and statistical results.

D. EXPECTED BENEFITS OF THIS THESIS

This research will assist network managers in assessing the impact of emerging technologies that utilize prioritization and chargeback mechanisms. Readers will benefit from presentation of a clear definition of network resources, which is unavailable from other information sources. They will gain an understanding of the histories of prioritization and chargeback, and will be provided a snapshot of prioritization and chargeback methodologies that are in use or are available. This research will explain the prioritization and chargeback options, their usage, and the advantages and disadvantages of each methodology. This thesis intends to expand on the traditional views of network management and to provide insight into alternatives to continued high-cost infrastructure upgrades within DOD computing networks.

II. BACKGROUND

A. INTRODUCTION TO NETWORK MANAGEMENT

The term "management" is defined below to build a basis for further detailed discussion of specific network management techniques.

1. Management Defined

According to the American Heritage Dictionary, to manage is:

- To direct or control the use of, to handle.
- To exert control over.
- To make submissive to one's authority, discipline, or persuasion.
- To direct the affairs or interests of.
- To succeed in accomplishing or achieving, especially with difficulty; contrive or arrange (1992).

Managing IT resources is a complicated and expansive task, which includes many areas of responsibility. In the business sense, management has always connoted optimizing the utility of available resources–in other words–making the most of what you have. In effect, the IT manager's responsibility is to control the use of his or her resources to create the greatest profit for an organization.

2. Network Management Defined

Network management attempts to optimize computing resources associated with networks. This is an especially difficult task in heterogeneous multi-vendor, multi-protocol, and multi-architecture networks.

> The phrase 'network management' is generally thought to mean, maintaining the performance of enterprise networks and optimizing traffic while keeping costs to a minimum. The word management indicates that the goal is to make the best use of the resources available (Wilson, 1996).

Divakara Udupa lists several specific goals of network management that reflect more than just traffic optimization and cost containment. These include:

•higher network availability,

- reduced network operational cost,
- reduced network bottlenecks,
- increased flexibility of operation and integration,
- higher efficiency,
- easier use, and
- increased security (1996).

Held declares "network management can be expected to balance performance and capacity while attempting to minimize costs" (1992). He identifies key functions of the network management process as the ability to recognize potential problems and the methods to resolve them. He accurately defines network management as:

> The process of using hardware and software by trained personnel to monitor the status of network components and line facilities, question end-users and carrier personnel, and implement or recommend actions to alleviate outages and/or improve communications performance as well as conduct administrative tasks associated with the operation of the network (1992).

This thesis is primarily concerned with using software to improve performance of the network through policy-based traffic control (prioritization), and with using software to conduct the administration task of charging network users for network resources (chargeback). In terms of the OSI framework for network management, this thesis is concerned with 3 out of the five areas:

- performance/growth management,
- security/access management, and
- accounting/cost management (Held, 1992).

Performance management involves evaluating network hardware resource utilization and adjusting variables as necessary with the intent to preclude communication bottlenecks and circumvent network overloads. Access management involves controlling user access to the network, making sure users have proper authorization. Accounting management involves tracking costs to formulate a basis for charging network customers for resources (Held, 1992). Figure 2 shows a breakdown of these network management functional areas and associated tasks.

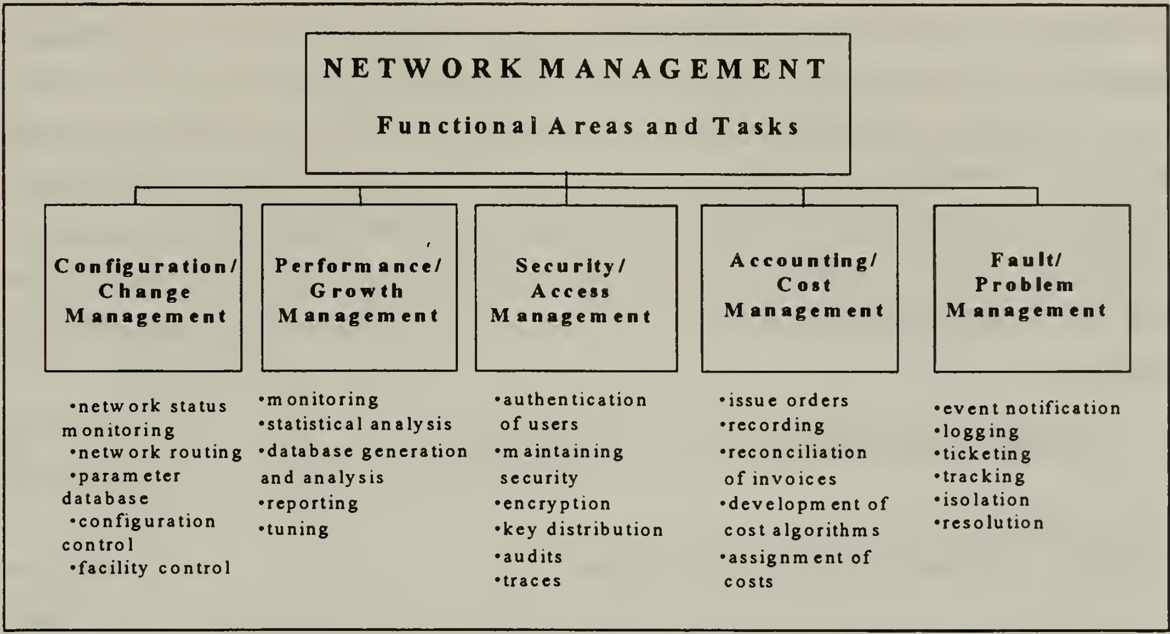

Figure 2. Network Management Breakdown (Held, 1992).

Of these three subsets of network management, this thesis is primarily concerned with performance management, which is:

> The monitoring of traffic flow within the telecommunications network, the optimizing of the traffic utilization of network resources, the preservation of the integrity of the network during high usage period, and the surveying of a network element's traffic processing behavior for network engineering and administrative purposes (i.e. network data collection) (Held, 1992).

"The goal of performance management is to maintain the quality of service (QoS) in a cost-effective manner" (Aidarous, 1994). Again, the goal of management is to create the highest corporate utility given the network resources. Performance management has two parts: performance monitoring and performance control (Aidarous, 1994). Performance monitoring is intended to track network activities and collect data for decision-making and trouble-shooting. Performance control involves modification of network parameters to provide the highest QoS to all users.

Policy-based network management in the form of prioritization can control which network users have access to network bandwidth according to predetermined corporate policies and the amount of bandwidth provided to the user or workgroup based on their location, the application(s) they are using, their position, or other parameters; thereby

controlling network performance in addition to network access. This type of mechanism can prevent or reduce congestion on a network running at near capacity levels.

Chargeback has traditionally been used to track CPU usage, beginning with mainframe time-sharing scenarios. With current computing networks, chargeback software can be used to control a user's network access by setting constraints on a user's account, and can reduce congestion by limiting network access. Chargeback can also be used as a cost management tool that shares network costs across organizational cost centers.

B. COMPUTING RESOURCE MANAGEMENT

1. Computing Resources Defined

Since the advent of computing, computing resource management has been discussed, studied, developed into theories, and then practiced. The objective of resource management has been constant while the resources themselves have changed with network evolution. These resources are the economic decision variables associated with computing. A network manager's business decisions are based on these variables and their tradeoffs. He or she will attempt to maximize the organization's computing power based on its business objectives, and will ask the question, "Where do I spend my time, money, and manpower to get the greatest computing resources for my users?"

In general, these computing resources are not particularly well-defined nor are they categorized in a consistent manner. "The challenge of sharing network resources...is neither well understood, not well catered for" (Jones, 1992). Many authors discuss network resources, but they have failed to adequately define them. The Resource Manager's Guide divides them into five areas of hardware, software, peopleware, firmware, and paperware (DSMC, 1990). These are a good starting point, but this is not an all-inclusive list. The authors believe that there are four classifications of computing resources:

- physical resources,
- logical resources,
- electronic resources, and
- time-based resources.

The first classification equates to hardware, but it can include peopleware. It consists of computer parts (CPU, monitor, input/output devices, peripherals) as well as the physical plant where these computers are located. Physical resources also include the connections between computers—the transmission medium itself, whether it's a telephone line, a Category 5 telephone line, a coaxial cable, or fiber optic cable. The paperware would be a physical resource as a system input or output. People are a combination of physical and logical resources, since they provide no value without knowledge.

Logical resources are the knowledge, information, or data that reside within a computer system. The majority of logical resources are software and stored data, but there is system information residing in people.

Electronic resources do not fit well into any of the resource "ware" categories, but are definitely user resources and economic decision variables. CPU cycles, computer memory, and network bandwidth are three such electronic resources.

The final category, time-based resources, is based on user access to resources, such as access to a workstation, and access to a network connection. These need to be considered a resource because although you may have all the necessary physical, logical, and electronic resources (a room full of workstations with all the peripheral equipment, the latest software, lots of RAM memory, a fast CPU, fiber-optic network connections running at 156 Mbps, and a fully manned help desk), if users do not have access to the workstations, or access to the network, the rest of the resources are useless.

2. Mainframe Computing vs. Distributed Computing

The differences between mainframe and distributed computing decision variables are illustrated in Figure 3. The mainframe economic decision variables have remained constant as network computing has evolved. However, the addition of several new network resources as decision variables has made making business decisions much more complex by creating many more tradeoffs for the manager to consider. "In the last 15 years, Local Area Networks (LANs) have gone from being an experimental technology to becoming a key business tool used by companies worldwide" (Bay Networks, 1997b). Network managers are being forced to contend with making complex resource decisions in an environment where the variables are constantly changing as technology advances. Although DOD recognizes the importance of managing its Command, Control, Communications, Computing and Intelligence (C4I) resources as part of network control,

and includes the analog RF spectrum as a resource (along with personnel and equipment), it does not recognize digital bandwidth as a resource (CJCS, 1995).

As organizations become increasingly dependent on information exchange, applications become more network-centric and reliance on the corporate network grows. This view of the business, application, and network challenges conventional wisdom which views the network as plumbing (Bay Networks, 1997a).

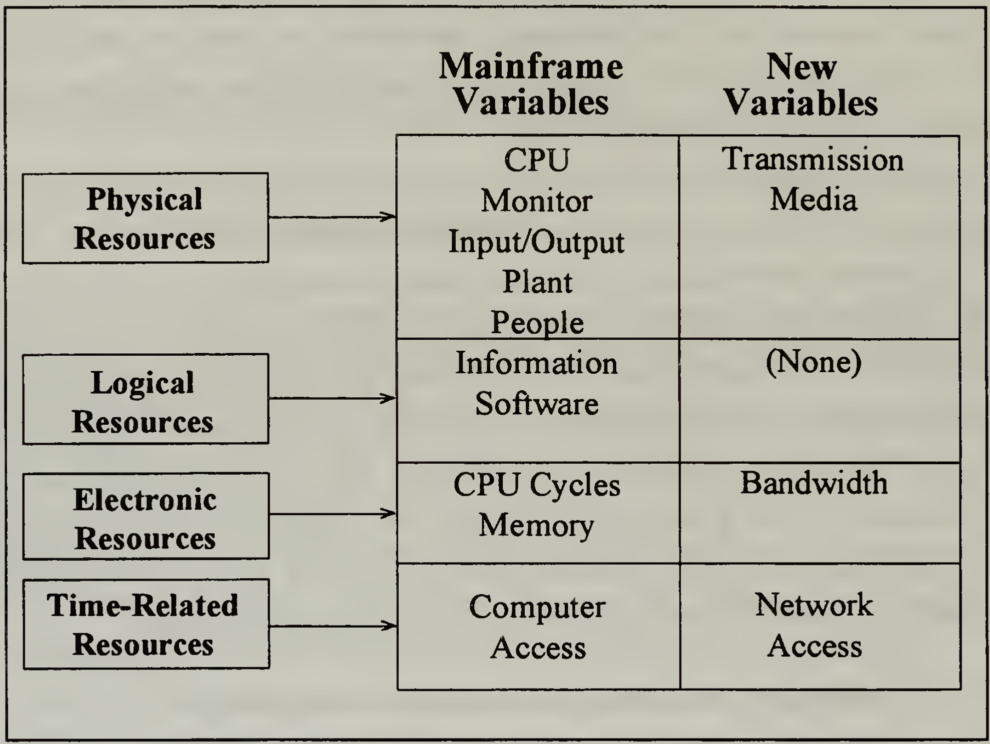

Figure 3. Changes in Computing Resources.

Changing decision variables are challenging the conventional wisdom, but they have yet to overcome the traditional views of computing resources where the network "plumbing" has been treated as a physical resource that needs to be replaced or upgraded. Of all the economic decision variables, only one has yet to be fully integrated as a resource variable–bandwidth. This thesis contends that network management methodologies have not effectively changed with the addition of network decision variables, but that network management methodologies are just beginning to consider bandwidth as a resource worth managing.

C. NETWORK RESOURCE MANAGEMENT METHODOLOGIES

Traditional management and resource control methodologies include issues concerning fault tolerance, configuration management, accounting, performance management, and security management. However, performance is the key concern to most MIS support personnel (Stevenson, 1995). Consequently, many network managers have focused on upgrading their current network infrastructure as one solution to support their organization's performance needs.

1. Infrastructure Management

Network infrastructure includes all equipment and connections necessary for a network to operate. This equipment might include cabling, routers, outlets, switching centers, servers, workstations, data centers, mainframes, etc. An analogous illustration would be all underlying equipment and connections necessary to provide electricity from a power company and distribute that electricity within your house (Hasenyager, 1996).

a. Definition

For the network manager, the term "infrastructure management" is defined in the context of the OSI network management model to include configuration management, fault management, and performance management. Traditionally, network managers have primarily focused on configuration management and fault management. This has included planning, provisioning, and traffic management. However, with the steady growth of organizational networks, and the proliferation of personal computers, more and more network managers are concerned with performance due to the increase in network congestion. Network complexities have resulted from the increasing requirements placed on the networks. Some requirements include multiple media, multiple services, high-speed, multiple switching technologies, and multiple protocols (Aidarous, 1994). In addition, the complexity continues to increase due to the need for interoperability and scalability across the increasing variety of platforms.

The ability of a network infrastructure to maintain its functionality decreases as organizational needs change over time. Consequently, the purpose for which an infrastructure is conceived and constructed must change over time. An unchanging infrastructure is ultimately unusable for new organizational purposes. For example, "a

network intended to support data communications between terminals and the mainframe is unsuitable when the requirement changes to audio, video, and image messages between work stations" (Hasenyager, 1996). The functionality of the network is the key to its survivability and its use.

The purpose of infrastructure management is to ensure that the underlying network structure is functionally adequate to support the changing business needs of the organization through use of configuration management, fault management, and performance management.

b. Techniques and Tools for Improving Network Performance

Since the early 1980's when local area networks (LANs) began to proliferate in campus and organizational environments, network managers have been faced with the problem of network congestion. As more and more connections were added and applications required additional bandwidth, network utilization increased. To minimize the congestion, network managers segmented large LANs into smaller segments using bridges. The bridges functioned to connect the small segments together while isolating local traffic on each segment of the LAN (Ipsilon Networks, 1996).

As bridged LANs grew larger, the problem of broadcast storms developed where high levels of broadcast traffic could saturate the network and result in the loss of large portions of the network. This resulted in additional broadcast traffic that exacerbated the problem. Consequently, routers were introduced in an effort to segment broadcast traffic and give network managers more control over broadcast domains (Taylor, 1996b).

In addition to the ability of routers to eliminate broadcast storms, the focus on internetworking in the mid-1980's created the market need for routers with the design capability to relay packets from almost any type of network to another. Improvements in routers included the addition of intelligence to allow routers to choose the most efficient path for network packets and to provide redundant paths in the event of a component failure (Ipsilon Networks, 1996).

Since the first implementation of shared LANs, applications have been created using Simple Network Management Protocol (SNMP) to give network managers the ability to monitor network traffic, perform fault management, and analyze congestion on network segments. A shared LAN is a network segment in which the available

bandwidth is shared with all other users on that segment (Slobig, 1997). Network management applications exist for measuring traffic levels on both a static and dynamic basis for shared LANs. Network Analyzers and sniffers are available to identify faults contained in subnets of complex networks. Remote monitoring (RMON) based solutions provide the network manager with the ability to poll distributed network agents and obtain data necessary for evaluating network performance trends. Additionally, the availability of RMON has given network managers the ability to monitor network performance from a centralized location.

Network management tools have evolved from simple diagnostic tools that rely on a network manager's own knowledge and experience to intelligent systems providing both automatic synthesis of network data and even some forms of automatic system control. "Legent's AgentWorks uses distributed agents to monitor operating systems and data bases for exceeded thresholds and then automatically responds to events via predefined actions" (Hume, 1997). Other intelligent system applications conduct analysis of fault alarms, provide probabilities for possible component failures, and recommendations for prompt restoration of the network. Vendors have also provided graphical user interfaces with real time displays of network performance measurements.

Although these management tools have improved the ability to monitor and evaluate the performance of networks, the "distributed client/server data traffic, expanded user populations, and more complex applications have created new bandwidth bottlenecks for shared-media networks" (Ipsilon Networks, 1996). Consequently, network managers are migrating to switched LANs in an attempt to increase capacity by increasing LAN segmentation (Taylor, 1996b). Switched LANs exploit the concept of LAN segmentation just as bridges did in the early 1980's and they are an effective economical alternative to routers. "Switches enable fine grained network segmentation and can deliver dedicated bandwidth per segment" (Ipsilon Networks, 1996). One effect of migrating to switched LANs is the inability to cost-effectively monitor network performance using analyzers or RMON probes. Because of fine segmentation, a probe would be required on each port of the switch. To overcome this limitation, some switch vendors are providing the performance management and traffic visibility through the use of switched network Monitoring (SNOM) and ATM Network Monitoring (AMON) based applications.

Additional advances in infrastructure management have resulted in the formation of virtual LANs (VLANs) as another mechanism created to logically (vice physically) segment broadcast domains. Further advances include the use of ATM in

switched LANs in an effort to again improve data transfer capacity and speed, reliability and quality of service, as well as improved scalability.

c. *Benefits/Drawbacks of Infrastructure Management*

Despite the advances in network management tools and applications, the methodologies of infrastructure management have not changed significantly. Network managers are still more focused on ensuring that the network operates than on ensuring that the network resources are being efficiently and effectively used. The use of network management tools can significantly increase the amount of overhead bandwidth used in the network for administrative functions such as the polling network agents. "So complex and tiresome has network management become to some companies that they have actually laid an extra cabling infrastructure to deal with the network management alone due to the loss of bandwidth" (Reid, 1995). Emphasis has been placed on managing hardware resources and logical resources than on holistically managing all network resources. "The network manager's job has changed from one of implementing and maintaining infrastructure to more holistic systems management" (d-Comm, 1995).

Network managers have been relying on Moore's Law (technology advances double every 18 months) and they have ignored Metcalf's Law (every time you add capacity to a communications pipe, the same demand in growth takes place) and the management of an important electronic resource–bandwidth.

Rather than optimizing network traffic on a particular link, many network managers respond to congestion by expanding network capacity. If a manager has plenty of bandwidth capacity and future bandwidth potential, he will benefit from using only infrastructure management. Yet if a manager is under-staffed, under-budgeted, and the network is running at near bandwidth capacity, the manager may be doing the organization a disservice by holding onto this infrastructure management paradigm.

2. Chargeback Control Methodologies

A chargeback system is intended to function as an IT management control system. An effective IT management control system ensures that, "IT is being managed in a cost-efficient, reliable fashion, on a year-to-year basis" (Applegate, 1996). Three fundamental objectives of IT management control systems include:

1. Simplify communications between the user and provider of IT services and provide incentives for them to work together on a recurring basis. The system should promote behavior that is in the best interest of the organization, motivate appropriate use of IT resources, and aid in balancing investments in IT against investments in other areas.

2. Encourage effective use of IT resources and educate users of the potential of current and future technologies. The management control system should align the transition of technology with the evolving strategic needs of the organization.

3. Provide the mechanism for effective management of IT resources while also providing the necessary information for making investment decisions (Applegate, 1996).

a. Purpose

The function of an effective chargeback system is to establish the proper balance between controlling costs, stimulating use, and encouraging efficient use of IT resources. By making users who consume IT resources responsible for their costs, chargeback systems should encourage more judicious use of IT resources, as well as promote a higher quality of service from providers (Rappaport, 1991).

b. Methodology Models

In the 1970's and early 1980's, using chargeback systems as an IT management control methodology focused on mainframes and data center technologies. Many data center managers used "chargeout" systems to inform users of the actual costs of executing jobs. When the data center managers billed for these costs, the system was referred to as "chargeback" (Schaeffer, 1987). "At the heart of the chargeback issue is the need to establish a clear set of financial and managerial objectives" (Rappaport, 1991).

The architecture of the IT management control system and its underlying philosophy influence the successful implementation of the control system. The three types of control architectures are an unallocated cost center, an allocated cost center, and a profit center. Other conceptual models that parallel these ideas include the socialist model, the communist model, and the capitalist model (Schaevitz, 1989). The IT manager's control architecture decision is, "a fundamental one; once made, it is not lightly changed, and the decision has very differing effects on behavior and motivation" (Applegate, 1996).

c. *Benefits/Drawbacks of Chargeback Methodologies*

(1) Unallocated Cost Center. The unallocated cost center offers IT resources to the user free of charge. Because users do not realize any cost, user access requests are stimulated and experimentation is encouraged. IT resource innovation for use in business is also promoted. In organizations that are in early phases of technology assimilation, this approach establishes strong IT-based influences within the organization. However, users perceive IT as free.

(2) Allocated Cost Center. An allocated cost center attempts cost recovery for IT resources. Users are charged based on a standard cost per unit of resource utilized, or based on division of all resource costs to users. Combinations of fixed and variable pricing structures are used to influence user behavior and to control the utilization of IT resources.

Allocated cost centers can provide a detailed breakdown on where IT expenses are occurring, and provide information on the costs that result from a given level of service to a given user or department. They can identify cost drivers that might otherwise not have been apparent to the IT manager. A cost driver is defined as "anything that when changed in scale or scope will generate a corresponding change in the infrastructure" (Bendor-Samuel, 1996). "If you do not have some sort of chargeback mechanism in place, there is a good chance outsourcers could come in and take away your business because you don't know what you are spending" (Cafasso, 1995). Although allocated cost centers can provide these benefits of cost identification and recovery, the architecture of the IT management control system and its underlying philosophy influence the successful implementation of the control system (Applegate, 1996).

Schaeffer identifies six disadvantages of chargeback systems as they relate to data centers (1987). The first disadvantage is wasted resources. Schaeffer argues that in contrast to saving resources, more resources will be wasted since within an organization a person's importance relates directly to the degree that the data center resources are utilized. Consequently, the person will increase use of that resource. The second disadvantage noted is decreased data center efficiencies. Schaeffer indicates that since costs have been transferred to users, data center personnel will become less concerned with efficiency. Additional disadvantages highlighted include: decreased innovation by both data center personnel and users, user alienation, and feelings of

inadequacy. Several of these disadvantages are actual dichotomies of the benefits described earlier for allocated cost centers.

In order to effectively implement an allocated cost center within an organization, the following characteristics are desired:

- users must understand it,
- the system must be perceived as fair or equitable, and
- it should distinguish IT efficiency from user utilization of the system (Applegate, 1996).

Other desired characteristics include:

- reproducibility,
- managerial control, and
- the ability to compare costs to other market references or alternatives (Rappaport, 1991).

By designing a chargeback system with these characteristics in mind and tailoring them to your organizational needs, the disadvantages as outlined by Schaeffer can be adequately addressed.

(3) Profit Center. The final architecture of an IT management control system is the profit center. The profit center is designed to "put the inside service on the same footing as an outside service and bring marketplace pressures to bear" (Applegate, 1996). It stimulates effective cost control by marketing itself as a cost effective alternative to outside services. IT management response time also improves. However, other adverse effects can result. One effect is undesired preferential treatment given to activities outside the organization which results in an erosion of service within the organization. Due to security concerns and privacy issues, other viable outside alternatives may not exist. Also, "at least in the short run, setting up the IT activity as a profit center leads to higher user costs, because a profit figure is added to user costs" (Applegate, 1996).

The control methodology that an IT manager decides to use must balance recovery of IT expenses while still promoting innovation and use. No one methodology alone will integrate seamlessly within an organization's structure. Factors affecting acceptance within the organizational culture largely depend on whether chargeback mechanisms have traditionally been a part of the organization and what level of technological maturity and dependency currently exist within the organization. "The challenge is to pick the one that best fits the company's general management control

culture, current user-IT relationships, and current state of IT sophistication" (Applegate, 1996). "The real-world requirement to balance network cost recovery with optimizing usage usually leads to chargeback system that incorporates aspects of all three models" (Rappaport, 1991).

d. *Evolution to Client/Server Environments*

In the early 1980's when the PC revolution began, certain applications began migrating to the desktop due to economic issues. Desktop hardware prices were dropping rapidly and PC capability was increasing at an exponential rate. The number of applications that could be used outside the data center environment grew, and the migration from data centers to desktops began. Continued improvements in hardware and software capability promoted further decentralization. The need for individual users to share information prompted the formation of networks. The economic advantage of less expensive hardware combined with increasing processing power created the ideal environment for the transition to distributed platforms and client/server applications.

> Technological price/performance improvements and management initiatives to make MIS more responsive to the operating units has led to widespread decentralization of data processing functions. Data networking has become the fundamental enabler of information sharing as organizations evolve from centralized to decentralized, and now to enterprise (or networked) computing (Rappaport, 1991).

Despite the hardware's lower costs in a distributed computing environment, costs are ultimately shifted to other areas. "When (information systems) departments are making the transition from mainframes to distributed architectures, they don't realize that managing these environments is three to six times more expensive than in a centralized mainframe environment" (Karon, 1994).

Although traditional mainframe chargeback solutions are well defined and understood, they do not translate well to the distributed computing environment. Managing access to shared resources is still fundamental, but, the electronic resource allocated is now shared media bandwidth instead of processor time. Network architecture complexities create difficulties in deciding whether to charge users based on data bits transferred or received, guaranteed bandwidth, responsive pricing models, or tiered pricing structures. The economic overhead of a chargeback system in a complex network can

also contribute to inefficient use of resources. "In one instant, a large multinational, multi-organizational company found that more than 50% of its total network costs were a direct result of its chargeback and usage monitoring" (Bendor-Samuel, 1996). Additional challenges in the client/server environment include recovery of hidden costs such as "customizing software, script writing, retraining and configuring software which account for 75% to 80% of the cost of implementation" (Karon, 1994).

In the face of inherent complexities and questions surrounding chargeback systems in the distributed computing environment, the need to identify and recover network costs is even more prevalent in DOD today due to the continually increasing IT demands and stagnant IT budget. "Conventional techniques of segmentation, firewalling, and adoption of faster shared-access LAN technologies has already begun to yield diminishing returns and cannot possibly serve as the foundation for a network that is expected to carry business into the next decade" (Bay Networks, 1997a).

3. Policy-based Management Methodologies

Before examining policy-based network management methodologies, terms used must clearly be defined. A policy is "a rule that an administrator places on the system, providing a way for an administrator to customize applications to organization-specific needs; policies are rules that govern the management of resources" (Simon, 1997). Policy-based software has been introduced as an automation tool for many areas of network management, such as:

- controlling network security and user access,
- scheduling background processing jobs,
- defining user-configuration profiles that control user access rights and start-up applications, and
- other network areas that already have policies (Graziano, January 1996).

Although there are numerous policy-based management applications, this thesis targets only policy-based traffic management using prioritization.

a. Background/Purpose

The practice of managing bandwidth by prioritizing message traffic in a communication system is not a new one. Military communications systems such as AUTODIN have been prioritizing messages by their operational urgency for decades,

sending flash (Z), immediate (O), priority (P), or routine (R) messages. The military services have dealt with severely limited transmission bandwidth, and have learned to optimize it effectively by prioritizing message traffic on satellite and RF wireless communication networks. They have implicitly understood the purpose of prioritizing network traffic—to make the best use of existing transmission capabilities and capacities. In today's military network environment, they have lost sight of this potential management tool for their computing networks which serve as their communication backbones. Organizations outside the military historically have not had as much exposure to such tools.

Bandwidth control is imperative in any network that is expected to perform well. At the heart of prioritization is congestion control. Network congestion is described by Waters:

> Congestion control is concerned with ensuring that a network can operate at an acceptable performance level even when it is heavily loaded. There are two principal ways of dealing with potential overload in networks. The first is to block new calls if they would lead to congestion; the second is to try to adapt to the situation (by creating new resources or by reducing the demand on the network or by degrading the service provided).
>
> Congestion occurs when a network resource is overloaded; the resource may be an individual session link, the buffer pool at an intermediate node or at the destination system or the processing capacity in one of these systems. Congestion may also be due to equipment failure. Jain showed that congestion control cannot be achieved simply by increasing the resources in the network in the form of buffer capacity or higher speed links. Nor can it be controlled by a balanced configuration; because of the unpredictable nature of the traffic, bottlenecks can still occur (1992).

The network overload that prioritization tries to alleviate is bandwidth overload, what Waters calls the "link" or "link speeds." Congestion has become an overwhelming problem due to the sheer volume of data being transferred across organizational distributed computing networks, as well as the diverse types of traffic moving through these networks. The mixing of these data types is commonly known as multimedia.

Multimedia has a very simple definition. It involves any combination of two or more of the following elements: text, image, sound, speech, video, and computer programs. These mediums are digitally controlled by a computer(s) (Acab, 1996).

Each of these elements has differing data transmission requirements. Chiang describes multimedia traffic characteristics and requirements:

> High-speed networks must support a variety of traffic with highly diverse characteristics. The growth of multimedia applications and the increase in the number of users demanding those services continue to push bandwidth requirements higher. Further, the real-time, interactive nature of these new services require low latency transport.
>
> Data transmission types can be divided into four categories:
>
> 1) bursty, low-speed–examples include remote logins, emails, and file transfer;
>
> 2) continuous, low-speed–examples include real-time voice transmission;
>
> 3) bursty, high-speed–examples include compressed video, image, and parallel computer interconnection; and
>
> 4) continuous, high-speed–examples include real-time uncompressed video.
>
> Ideally, networks must simultaneously support all four categories of data with acceptable efficiency (1996).

Not only does multimedia deal with differing types of traffic, but in today's networks, it also includes issues of multiple architectures and protocols. "The goal of multimedia networking is to deal with variety of protocols and topologies, providing data transfer with very high speed and very large bandwidth" (Liu, 1996).

Taking into account the nature of multimedia, "priority in processing network requests is critical" (Liu, 1996), although the common attempt to control network congestion has been creating larger, faster links–by expanding the bandwidth capacity. This is done by upgrading with technology or architectures that provide the increased bandwidth. Examples are:

- shared Ethernet migrated to switched Ethernet,
- shared or switched 10 Mbps Ethernet migrated to Fast Ethernet,
- Token Ring migrated to FDDI, or

•any architecture migrated to ATM.

Mackie-Mason calls this solution to congestion "overprovisioning." Both he and Wilson view this as an inefficient and expensive solution.

> A completely different approach to reducing congestion is purely technological: overprovisioning. Overprovisioning means maintaining sufficient network capacity to support the peak demands without noticeable service degradation. This has been the most important mechanisms used to date in the Internet. However, overprovisioning is costly, and with the very-high-bandwidth applications and near-universal access fast approaching, it may become too costly (1995).

> The most common means of solving network problems and bottlenecks is simply to throw bandwidth at the problem. Rather than optimize the traffic on a particular link, most network managers respond to congestion by expanding network capacity. This approach may be the easiest, but, it is often the least efficient and most expensive (Wilson, 1996).

A better, more efficient solution to managing network congestion is to prioritize the multimedia traffic or invoke QoS mechanisms. Wilson claims that network management is becoming a business-oriented, strategic planning function rather than the technical, traditional trouble-shooting function (1996) which revolves around infrastructure management. The authors believe that this business-oriented network management should be centered around efficient use of bandwidth resources.

Quality of service (QoS) differs slightly from prioritization, but both are closely related, and involve controlling resources. QoS is "the service level defined by a service agreement between a network user and a network provider, which guarantees a certain level of bandwidth and data flow rates" (Simon, 1997). A network service provider or network manager may promise a specific throughput or bandwidth (QoS), and prioritize traffic in order to achieve the service that has been promised to a user. QoS issues involve delay sensitivity or latency of traffic, as well as throughput demanded by an end user. Prioritization achieves these demands. Both QoS and prioritization regard bandwidth as a network resource that is important to access and control.

Any discussion of network management must include some discussion of the Internet. The Internet has been a catalyst for the wide-spread use of networks, the proliferation of multimedia applications, and the need for achieving QoS and prioritization in data transmission. Many organizations consider their Internet access and their external network connection as a vital strategic IT resource. This usage has created a need for

QoS routing and standardized methods for transmitting different data types, and has produced many effective standards and protocols. The Internet has become the catalyst for many de facto network standards, and is influencing the development of further standards. These standards originated with the TCP/IP protocols and X.25 architecture standards, and continue to expand.

Many congestion control techniques have been implemented since the creation of the Internet to improve transmission capacity. These techniques include: data compression, signaling/coding schemes, and improved transmission medium. Each allows more data to be sent across a link.

The most recent technology that has dramatically expanded network capacity is switching. Initially, most, if not all, network traffic was transmitted using routers which directed traffic according to the Internet Protocol (IP) addresses assigned to the data packets. The router essentially looked up each individual packet address at the network layer and routed the packet as appropriate. The concept of switching a packet directly to its destination without processing its layer 3 header has been a boon to solving the problem of network congestion. Switches perform at the OSI layer 2 (the data link layer) while routers perform at the OSI Layer 3 (the network layer), which makes them faster and less administratively demanding than routers, since only the Layer 2 header is used. Specifically, 802.3 Ethernet switches allow each member of a subnet to have its own dedicated 10 Mbps of bandwidth versus sharing the same 10 Mbps with other users on the subnet. Routers also required that LAN segmentation be done by adding ports. Switches have eliminated this necessity and they provide easy LAN segmentation. This gives network managers obvious reasons to choose switching as part of their network architecture–better performance and decreased administrative workload.

b. Familiar Network Architectures

Since network bandwidth has increased to keep up with demand, prioritization has been accomplished using a simple first-come, first-served methodology (no prioritization at all) (Cooper, 1996) or has been restricted to computing resource access only.

Many traditional network architectures have taken prioritization into account, and have been designed with prioritization capabilities in mind. However, some

of the most commonly used architectures do not. Several familiar and widely used network architectures and technologies are listed in Table 1 and are described below.

Table 1. Familiar Network Architectures.

Architecture	Bandwidth Capacity	Levels of Prioritization	Network
802.3 Shared Ethernet	10 Mbps per subnet	None	LAN
802.3 Switched Ethernet	10 Mbps per node	None	LAN
802.4 Token Bus	4 Mbps	8	LAN
802.5 Token Ring	1 Mbps–16 Mbps	8	LAN
FDDI	100 Mbps	8 (Asynchronous)	LAN/MAN/WAN
FRAME RELAY	2 Mbps	2	MAN/WAN
ATM	155 Mbps-622 Mbps	2	LAN/MAN/WAN

(1) SNA. IBM's System Network Architecture is not only one of the earliest network architectures, but it is also one of the first architectures to implement prioritization to manage network traffic. SNA was created in 1974, and the 1979 version included Class of Service (COS) routing, which included three types of service: interactive, batch, network control, and others defines by the users. A requested COS was obtained upon the connection required by SNA's connection-oriented service, and this COS was maintained throughout the session. Added later, transmission priority based on a session's COS allowed more important traffic (interactive) to be transmitted prior to batch processing traffic. This routing was configured by administrators until IBM introduced dynamic routing in its Advanced Peer to Peer Networking (Crawley, 1997).

(2) Ethernet. IEEE 802.3 specifications provide standards for Ethernet LANs using Carrier Sensed Media Access / Collision Detection (CSMA/CD). These networks operate as broadcast networks, and are not designed for prioritizing data traffic. "802.3 frames do not have priorities, making them unsuited for real time systems in which important frames should not be held up waiting for unimportant frames" (Tanenbaum, 1988). A recent exception is the development of Isochronous Ethernet 802.12 standard, which has provided Ethernet for real time systems. This advanced Ethernet standard is discussed in the next section as a recent method of bandwidth management. The 802.3 frame is illustrated in Figure 4, notably devoid of prioritization notation or tagging.

(3) Token Bus. IEEE 802.4 specifications define standards for token bus LANs. This standard includes four priority classes (0,2,4,6) with 0 as the lowest priority and 6 as the highest. Within a token bus frame, the priority is indicated in

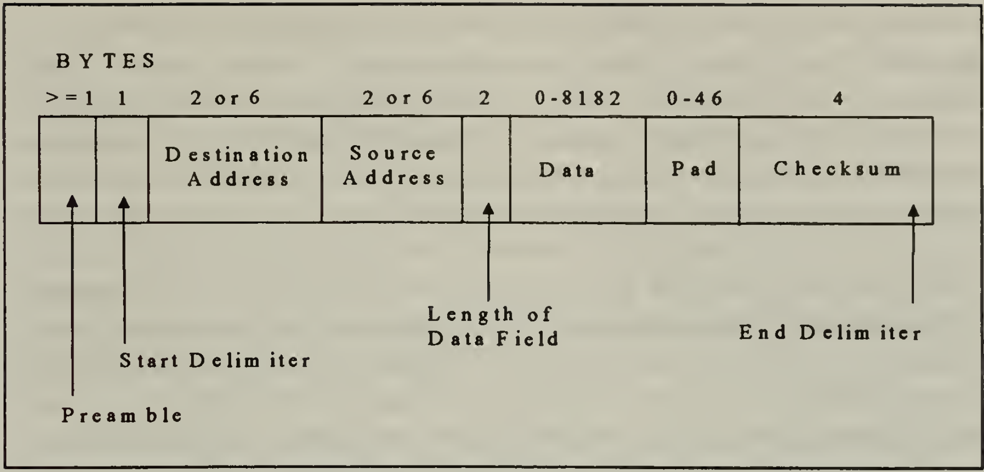

Figure 4. IEEE 802.3 Ethernet Frame (Tanenbaum, 1988).

the frame control field along with bytes that indicate whether the frame is a control frame or a data frame. (Only data frames are prioritized when using token bus architecture.) The 802.4 token bus frame format is illustrated in Figure 5.

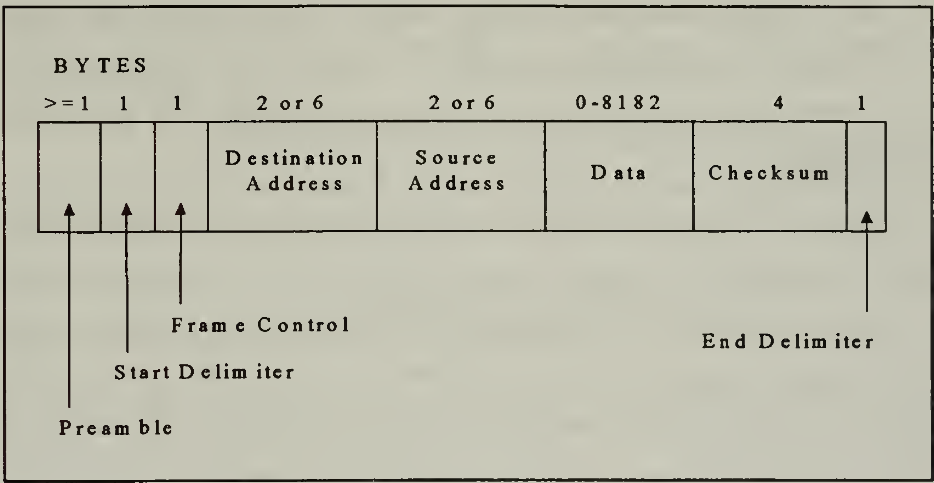

Figure 5. IEEE 802.4 Token Bus Frame (Tanenbaum, 1988).

Tanenbaum describes the methodology used to implement prioritization within token bus networks:

> It is easiest to think of each station internally being divided into four substations, one at each priority level. As input comes into the MAC sublayer from above, the data are checked for priority and routed to one of the four substations. Thus each substation maintains its own queue of frames to be transmitted. When the token comes into the station over the cable, it is passed internally to the priority 6 substation, which may begin transmitting frames, if it has any.

When it is done (or when its timer expires), the token is passed internally to the priority 4 substation, which may then transmit frames until its timer expires, at which point the token is passed internally to the priority 2 substation. This process is repeated until either the priority 0 substation has sent all its frames or its timer has expired. Either way, at this point the token is sent to the next station in the network.

Without getting into all the details of how the various timers are managed, it should be clear that by setting the timers properly, we can ensure that a guaranteed fraction of the total token holding time can be allocated to priority 6 traffic. The lower priorities will have to live with what is left over. If the higher priority sub stations do not need all of their allocated time, the lower priority substations can have the unused portion, so it is not wasted.

This priority scheme, which guarantees priority 6 traffic a known fraction of the network bandwidth, can be used to implement voice and other real time traffic (1988).

(4) Token Ring. IEEE 802.5 is the standard for Token Ring networks. This network architecture provides for eight levels of priority which are indicated in the access control byte along with the reservation bits. The Token Ring frame is illustrated in Figure 6.

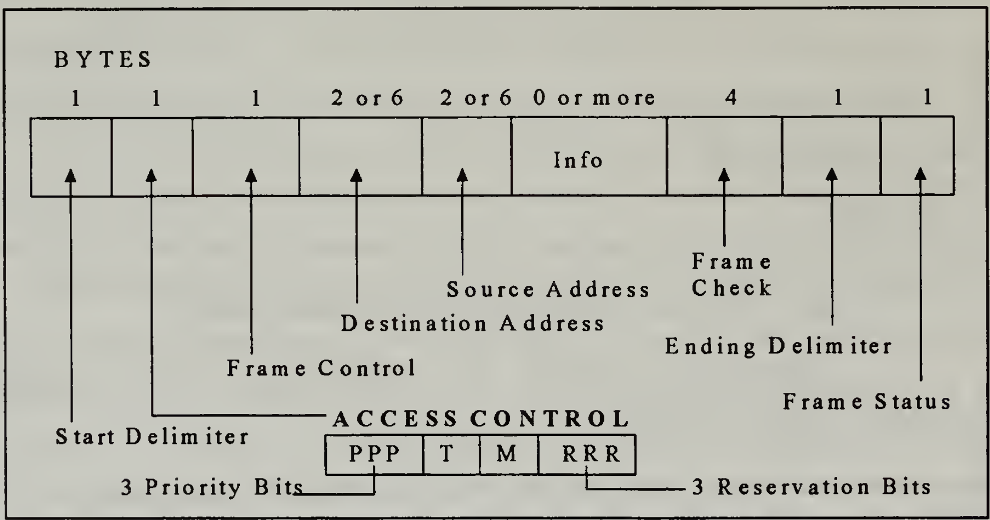

Figure 6. IEEE 802.5 Token Ring Frame (IEEE, 1989).

The 802.5 protocol has an elaborate scheme for handling multiple priority frames. The 3-byte token frame contains a field in the middle byte giving the priority of the token. When a station wants to transmit a priority *n* frame, it must wait until it can capture a token whose priority is less than or equal to *n*. Furthermore, when a data frame goes by, a station can try to reserve the next token by writing the priority of the frame it wants to send into the frame's *Reservation bits*. However, if a higher priority has already been reserved there, the station may not make a reservation. When the current frame is finished, the next token is generated at the priority that has been reserved (Tanenbaum, 1988).

The effect of the above steps is to sort out competing claims and allow the waiting transmission of highest priority to seize the token as soon as possible. A moment's reflection reveals that, as is, the algorithm has a ratchet effect on priority, driving it to the highest used level and keeping it there. To avoid this, two stacks are maintained, one for reservations and one for priorities. In essence, each station is responsible for assuring that no token circulates indefinitely because its priority is too high. By remembering the priority of earlier transmissions, a station can detect this condition and downgrade the priority to a previous, lower priority or reservation (Stallings, 1992).

Token Ring prioritization methodology differs from token bus in its use of both priority and reservation bits, but it also provides higher quality service for higher priority traffic. "In the Token Ring, a station with only low priority frames may starve to death waiting for a low priority token to appear" (Tanenbaum, 1988). Token bus provides an equal share of the network bandwidth to all stations, where Token Ring caters to high priority traffic. Because of the inherent prioritization potential built into the Token Ring architecture, many researchers have attempted to improve its performance by building on the 802.5 protocol standard (Bose, 1991) (Cohen, 1994) (Chang, 1991).

(5) FDDI. Fiber Distributed Data Interface (FDDI), defined by ANSI X3T9.5 in 1988, is an architecture that resembles the Token Ring architecture (using token-passing as its access method). FDDI differs in its 100 Mbps data transmission rate and its use on only optical fiber networks. It also differs in allowing a station to put a new token on the network as soon as it has transmitted its frames, using a timed-token passing protocol. FDDI-II provides packet and circuit-switched services, enabling transmission of all data types.

FDDI allows for eight priority levels, as does Token Ring, and it operates in much the same manner as the Token Ring architecture, but the token-passing

is timed, providing capability for synchronous traffic transmission. The priority bits are located in the Access Control byte of the FDDI frame shown in Figure 7.

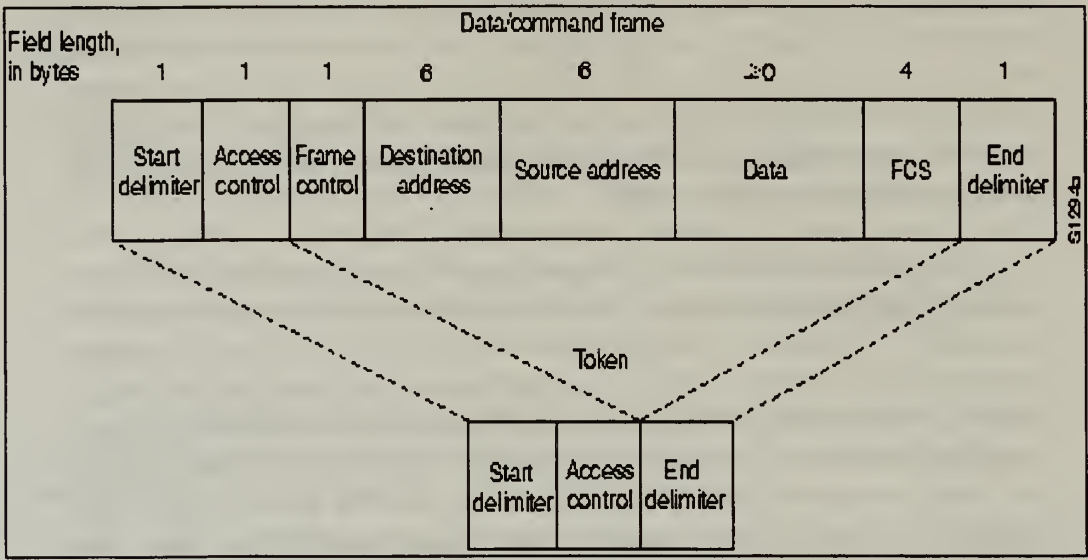

Figure 7. FDDI Frame Format (Cisco, 1996a).

Asynchronous bandwidth is allocated using an eight-level priority scheme. Each station is assigned an asynchronous priority level. FDDI also permits extended dialogues, where stations may temporarily use all asynchronous bandwidth. The FDDI priority mechanism can essentially lock out stations that cannot use synchronous bandwidth and have too low an asynchronous priority.

FDDI supports real-time allocation of network bandwidth, making it ideal for a variety of different application types. FDDI provides this support by defining two types of traffic: synchronous and asynchronous. Synchronous traffic can consume a portion of the 100-Mbps total bandwidth of an FDDI network, while asynchronous traffic can consume the rest. Synchronous bandwidth is allocated to those stations requiring continuous transmission capability. Such capability is useful for transmitting voice and video information, for example. Other stations use the remaining bandwidth asynchronously. The FDDI SMT specification defines a distributed bidding scheme to allocate FDDI bandwidth (Cisco, 1996a).

(6) Frame Relay. Frame Relay technology provides packet switching to networks without the error correction of X.25 networks, thereby decreasing the transmission time and the overhead (only 7 bytes per frame) required to transmit data. Frame Relay standards are defined in the ANSI T1.6XX series. The format for Frame Relay frames is illustrated in Figure 8.

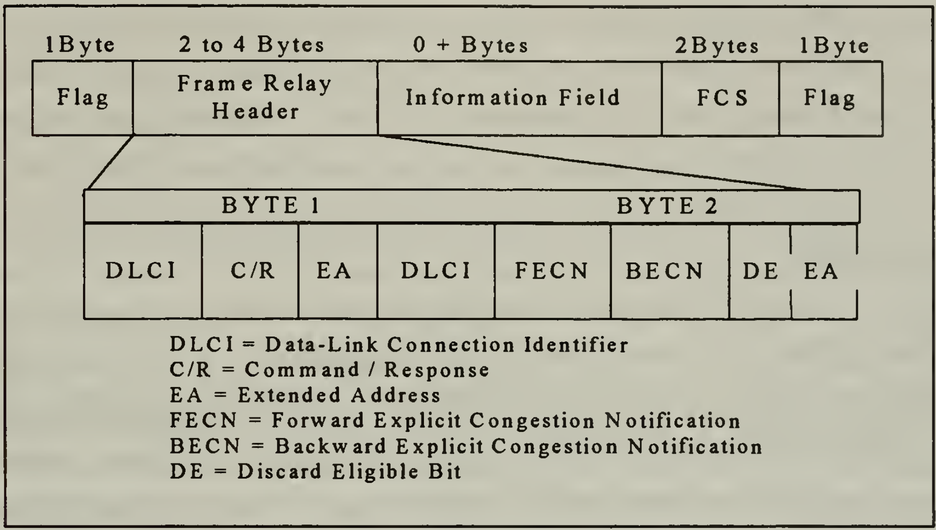

Figure 8. Frame Relay Frame Format (Feibel, 1995).

Frame Relay is essentially X.25 store-and-forward packet switching without the extended error control, so it has a faster transmission rate (Stern, 1997). It implements a “leaky bucket algorithm” using the discard eligible (DE) bit to achieve prioritization.

There are two virtual frame buckets. The first, which holds frames with DE bit set to 0, contains information that must not be discarded. The second holds the frames with the DE bit set to 1, which means that these frames are less important, and can be discarded if necessary (when the pipe is congested). For a public Frame Relay network, QoS is implemented using the Committed Information Rate, which is buying or leasing a specific size “pipe” which information is sent down. Both buckets fill this pipe to capacity (Stern, 1997).

Frame Relay congestion control mechanisms notify source/destination of congestion, but there are no guarantees of either delivery or relief from congestion. Frame Relay is not very good for traffic that requires low delay and the store-and-forward nature of packet-switching technologies doesn’t produce synchronous receipt of messages.

Currently, Frame Relay is being implemented in public networks with priorities by MCI and other Frame Relay providers. This prioritization will be briefly discussed in the emerging technologies section.

(7) ATM. ATM (cell relay) provides packet-switching using fixed size (53 Byte) cells instead of the variable length frames that are used in Frame Relay. ATM functions one step beyond Frame Relay, solving the problem of running multiple data types with differing multimedia requirements over the same network. This allows ATM the potential to provide QoS guarantees. "ATM is a switching architecture...each node can have a dedicated connection to any other node" (Feibel, 1995) provided the connection is ATM architecture end-to-end. The hardware itself accomplishes the routing along the connection.

ATM provides a "fat pipe" for the network, as it runs on fiber, and can use SONET, DS3, 100 Mbps, or 155 Mbps connections. It uses switched virtual circuits (SVC) and permanent virtual circuits (PVC), but prebuilds all switching circuits to save time. Similar to Frame Relay, it has no error correction, and it uses a leaky bucket algorithm, and has Cell Loss Priority (CLP) similar to Frame Relay's Discard Eligible bit.

The ATM Adaptation Layer (AAL) translates data into appropriate protocol for transmission at both source and receiving ends of transmission. These four classes are:

•Class A–Constant Bit Rate (CBR)/Voice–AAL1

•Class B–Variable Bit Rate (VBR)/Video–AAL2

•Class C–Connectionless–AAL4

•Class D–Connection-oriented–AAL3 & AAL5

The Asynchronous Transfer Mode (ATM) network architecture has been standardized, and it provides these AAL mechanisms to transmit multiple data types across the network, which has almost become a necessity in managing the increasing requirements of networks. Unless ATM is implemented from end-to-end in a network, the QoS has no guarantees. For organization implementing ATM only as a campus backbone, this will lose QoS as the backbone reaches capacity levels and congestion occurs.

The data classification schemes allow for dedicated bandwidth for constant bit rate (CBR) and variable bit rate (VBR) traffic, while the remaining types are unknown bit rate (UBR) and available bit rate (ABR). Both CBR and VBR traffic can negotiate and receive a dedicated portion of the bandwidth on an end-to-end ATM

connection, while UBR and ABR traffic are left to compete for the remaining bandwidth. This is a very simple method to achieve priority by application type.

(8) Apple. LocalTalk and Appletalk architectures are not discussed due to their proprietary nature and limited usage within the DOD, which is committed to using open network architectures.

In general, these network architectures allow prioritization tagging of data frames or some way to delineate the type of traffic, and are intended to transmit the data per its priority tag or traffic type. Prioritization has been always envisioned as a bandwidth management practice, but has not been adopted as a de facto standard.

> Technically, so far, we've only seen schemes that work at a single layer in the ISO model: 802.5 (Token Ring) and FDDI would only work within a single segment, if they were implemented at all. (The chipsets support priorities, but the NIC boards do not.) There used to be two flavors of X.25–basic and standard. The standard version was a DISA tweak that allowed four precedence levels (Z, O, P, R, naturally). It was demanded on some contracts, and dutifully supplied by a few vendors, but it was never used. Frame Relay has Discard Eligible which in effect provides two levels of priority. But this is a Frame Relay congestion control technique and is not apparent to users. There are more prioritization schemes, but few get used. And in terrestrial network there are few reasons to use them. It is cheaper to buy more bandwidth (a larger pipe) and heavier routers (Buddenberg, 1997).

Recent and emerging prioritization methodologies, protocols, products, and architectures may modify this view. These frontier developments are discussed in the next section.

c. *Recent/Emerging Bandwidth Management Methodology Models*

The simplest of all bandwidth management methodologies is a "best efforts packet service" or a "first-come, first-served with no guarantee of success" (Mackie-Mason, 1995). Although this method of managing bandwidth has been widely utilized to date, many network standards bodies, carriers, and vendors have taken steps to address the inevitable issues of providing multimedia QoS. Several recent/emerging bandwidth management methodology models are provided below to illustrate some of the technologies expected to be found in use by survey respondents.

(1) IPv6. The IETF Internet Protocol Next Generation (IPng) working group has provided means to sent priority packets in packet switched traffic over the Internet by including a priority field in the universal address of IP packet address of Internet Protocol version 6 (IPv6). The priority field is to be used by current Internet routing protocols. The field consists of 4 priority bits labeled H, R, D, and I.

- High Priority Bit (H)–Indicates packets that are critically sensitive to queuing delay and loss. Routers should schedule these packets first.
- Reserved Bit (R)–Not developed yet, but potentially will indicate packets of a flow for which the host has transmitted RSVP PATH messages, optimizing RSVP packet classification within routers.
- Drop preference (D) –indicates packets which can be lost without critically impairing performance of the application.
- Interactive (I) –Indicates sensitivity to queuing delay but no high throughput requirements (I.E. telnet) (Blake, 1997).

These bits have yet to be implemented as tags for IP message traffic.

(2) RSVP. The Resource Reservation Protocol (RSVP) is an internetworking protocol based on the current TCP/IP protocols that have become the de facto standard of most networks (and is designed to work using IPv6). It is an end-to end, receiver-based protocol which relies on the receiver of the data flow to initiate and maintain the data flow and its accompanying resources (Cisco, 1996b). This protocol has emerged as a way to achieve QoS across the Internet using current transport protocols.

Essentially, RSVP allows the receiver to request a specific allocation of bandwidth for use with delay-sensitive applications like voice or video conferencing. Each router along the path between sender and receiver has to acknowledge and approve the request for resources. Once this request is accomplished, it allows the sender and receiver a dedicated portion of bandwidth to use for a specified period of time for their data stream. Making a reservation involves two modules, the admission control and policy control modules. The admission control determines if the requested bandwidth is available, while the policy control determines if the user is allowed to make the reservation (Zappala, 1996).

There are two levels of service available with RSVP. These are controlled load and guaranteed service, both working from router to router to request the reservation.

> Controlled load allows packets to be assigned priority, so that they're not kept waiting in router queues as they cross the network. This is a best-effort service for priority packets. If congestion gets heavy enough, controlled-load packets could be dumped–although this won't happen as long as there are no-priority packets to be sacrificed. Guaranteed service, in contrast, reserves a specific amount of bandwidth. These packets will not be junked–as long as the traffic doesn't exceed the reserved capacity (Roberts, 1997b).

RSVP holds much potential for providing necessary controls on IP networks, but it is still in development, and is not expected to be on the market until 1998 (Estrin, 1996). It will potentially provide exactly the resource management methods that are discussed in this thesis (chargeback, policy-based management, and prioritization), provided it can overcome the routing, policy control, and oversubscription problems (Roberts, 1997b). RSVP will be a network management practice to watch closely in the next few years. It may prove to be a solution to many bandwidth allocation problems, or it may fall to the wayside and fail to meet the QoS requirements placed on it.

(3) Iso-Ethernet. The IEEE 802.9a for Isochronous Ethernet Integrated Services, approved this year, provides a potential solution for transmitting multimedia over existing shared Ethernet infrastructures. This non-priority technology solution adds 6.144 Mbps of switched ISDN circuits to conventional shared media Ethernet and uses more efficient coding schemes to achieve transmission of isochronous traffic like voice and video. It has a P channel of 10 Mbps Ethernet (10BaseT) plus full duplex 6.144 Mbps of switched ISDN circuits, which are essentially parallel serial connections for the isochronous traffic. The additional 6.144 Mbps ISDN line is composed of 96 switched 64 Kbps ISDN B channels for data traffic and one ISDN D channel for control and signaling. These ISDN B channels are signal-switched. As with any ISDN solutions, it requires installation of isochronous adapters on the computers (Brand, 1995). Although Iso-Ethernet currently is not a policy-based/prioritization solution, it has the potential to use prioritization, and it does allow for QoS requirements to be met.

(4) Switching and Routing. Switching and routing solutions which address the question of how to provide multimedia QoS with minimal congestion and

maximum value throughput are being developed by individual vendors as well and standards bodies. The Internet Engineering Task Force (IETF) has addressed issues of QoS-Based Routing as “the missing piece in the evolution of QoS-based service offerings on the Internet” in its Internet draft entitled “A Framework for QoS-based Routing in the Internet.” This document aims to “describe the QoS-based routing issues, identify basic requirements on intro and interdomain routing, and describe an extension of the current interdomain routing model to support QoS” (Crawley, 1997). It asserts that routing should be based on some knowledge of available resources, and one of the objectives should be “optimization of network usage: A network state-dependent QoS-based routing scheme can aid in the efficient utilization of network resources by improving the total network throughput” (Crawley, 1997). It discusses QoS determination, resource reservation, metrics and path computation, intradomain and interdomain routing requirements, QoS multicast routing, and RSVP protocols. It is a general discussion of the topic, but it provides a comprehensive discussion of many of the issues surrounding QoS routing.

Routing itself has evolved from simple TCP/IP routing to switching combined with routing. A potential solution to providing QoS routing is use of a route server, which combines these functions and allows a central control point for optimizing network performance.

> A route server receives network topology and state information from all network switching/routing nodes and thus is in a position to globally optimize the performance of the network. Paths for traffic to be sent across the network are calculated by the rough server using an approach that can best be characterized as “route once, switch many.” The route server control point only gets involved once during the initial call or session setup, determining the route and passing this information to each of the switching nodes along the chosen path; data exchanged between session partners never has to flow to or through the route server. After this initial activity, session traffic is simply switched or forwarded along the chosen path (Decisys, 1996).

With the use of central route servers, the potential for many-types of policy-based routing decisions emerges. Some factors used to determine optimal paths through a network may be:

- prioritization by application,
- reservation of bandwidth,

•costs of the transmission facility, and
•broadcast efficiency (Decisys, 1996).

Several vendors who have provided this type of QoS routing solution are IBM (Multiprotocol Switched Services–IBM's Switched Virtual Networking), Newbridge networks (VIVID), MadgeOne, Cabletron (SecureFast Virtual Networking), and Ipsilon Networks (IP Switching) (Decisys, 1996). All are proprietary architectures at this point, and do not provide QoS routing using open systems architectures, but the use of such architectures hails the permanent presence of traffic prioritization.

The ATM architecture is the only one that has achieved common standards in this area of routing. A few of the ATM standards related to routing are listed:

- LAN Emulation (LANE): Enables ATM and non-ATM devices to communicate through an ATM cloud and lets existing applications run over ATM.
- Multiprotocol over ATM (MPOA): Adds a route-server function to ATM networks and supports multiple protocols.
- Private Network-to-Network Interface (P-NNl) : Enables switch-to-switch communications and route calculation.
- Integrated P-NNI (I-PNNI) : Provides IP with P-NNI routing capabilities and performs route calculation on an end-to-end basis.
- P-NNI Augmented Routing (PAR): Supports internetworking between P-NNI networks and IP-based routing protocols (Dobrowski, 1996).

5) 100VG-ANYLAN. The IEEE 802.12 standard for 100VG-ANYLAN provides a Fast Ethernet priority solution over existing Category 3 and Category 5 cabling. It uses Demand Priority Protocol, which tags each packet as normal priority or high priority. The hub (or any other higher-level node) acts as arbitrator. The node requests to transmit a packet, the higher-level node conducts round-robin arbitration sending high priority requests first, one packet per node per round robin pass (Ocampa Technologies, 1997). Like the 802.5 Token Ring standard, the priority of a packet is raised after a specified time limit spent in the queue, converting it to high priority and sending it during the next round of arbitration. This solution does provide prioritization of

traffic, but it does not resolve the need to transmit isochronous traffic, nor does it completely meet the need for prioritization, since this standard could still lead to massive congestion as all the packets eventually get their priority raised, and the high-priority traffic could get slowed significantly by the normal priority packets that have simply been in the queue too long.

(6) IEEE 802.1q and 802.1p. The IEEE 802.1q Virtual LAN (VLAN) standard creates a switched network that is logically segmented by functions, project teams, or applications without regard to the physical location of users (Cisco, 1997b). It is "a capability somewhat similar to policy-based routing that delivers only a subset of its capabilities" (Decisys, 1996). This is done through tag switching of the traffic by the logical subnet that the user is assigned to. It allows users to keep their network addresses no matter where they are working and it reduces broadcast traffic by keeping broadcast traffic within VLAN domains. VLANs assist in managing bandwidth by freeing bandwidth from broadcast use, making it available to use for real user traffic, and by lowering vulnerability to broadcast storms. Currently there are seven possible types of VLANs:

- Port-based
- MAC address
- Layer three
- Protocol Policy
- Multicast
- Policy-based (not prioritization)
- Authenticated user (Xylan, 1997).

Although VLAN is currently not a prioritization method, it is a stepping stone for prioritization of network traffic, as it provides a method for grouping users, ports, or subnets. This grouping protocol will provide a means to apply priorities in the future through its tag switching.

The IEEE 802.1p standard for Expedited Traffic and Multiclass Filtering will provide a "signaling scheme that lets end-stations request priority and allows switches to pass these requests along the path" (Roberts, 1997a). 802.1p is still in development stages, and is intended to work with the 802.3x Gigabit Ethernet architecture to provide QoS.

(7) Frame Relay. Advances in Frame Relay include the addition of priorities to public carrier networks. MCI has divided Frame Relay permanent virtual

circuits (PVC) into three priority levels using Cascade Communications hardware switches:

1. The first will be designed for time-sensitive traffic such as SNA or voice;
2. the second for important, but non-mission-critical traffic; and
3. the third for low-priority traffic (Pappalardo, 1997).

This will provide Frame Relay users with additional QoS guarantees not provided by the previous leasing of Frame Relay pipes, which guaranteed only the bandwidth using committed information rate. This is a temporary solution to providing better, optimized service on a leased line, but "the (Frame Relav) networks that are deployed have plenty of switch and bandwidth capacity, but when they get fully rolled out, users are going to experience levels of congestion that will be unacceptable" (Pappalardo, 1997). An advance like this doesn't necessarily provide the users with a better solution to congestion, but it does provide the carriers a way to charge higher prices for the same amount of bandwidth. Other switch vendors like Northern Telecom have also produced switches that allow for prioritization on Frame Relay SVCs (Greene, 1997).

(8) ADNS. The Navy has developed its own network architecture that utilizes prioritization to provide bandwidth management. While still in its testing and implementation phase, the Automated Digital Network System (ADNS) provides bandwidth management beyond the four levels of standard IP message prioritization on a single communications link. ADNS provides an architecture for a mobile TCP/IP network that is specially designed for Naval Communications. Although tailored for use in navy specific applications, ADNS uses open systems protocols, commercially available equipment and architectures to utilize available RF bandwidth.

In essence, ADNS uses the Open Shortest Path First/Multicast Open Shortest Path First (OSPF/MOSPF) routing protocols which allow for dynamic route selection based on metric values (capacity, delay, reliability and cost). The OSPF protocol defines Autonomous System (AS) domains, areas and backbone networks to minimize the distribution of routing information. ADNS provides traffic management across the many mobile communications links using these protocols. Figure 9 is an overview of the ADNS system.

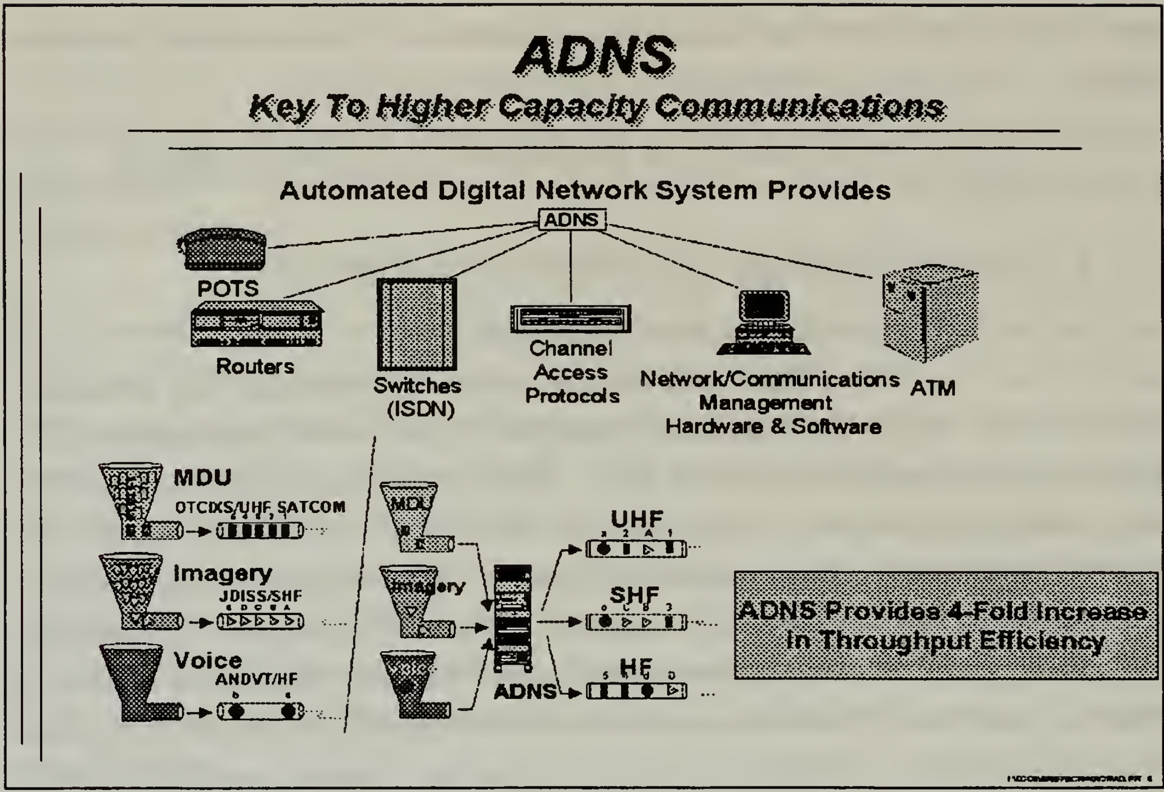

Figure 9. Overview of ADNS System (JMCOMS, 1997).

Figure 10 illustrates a generic Navy AS Architecture, and shows the relationships between the nodes of the ADNS network. Each ship or shore station within the AS is a node, whose architecture is similar to the node illustration provided in Figure 11.

Network management occurs within the node by priority assignment, queue thresholds, and routing metric values. These take place within the router, the CAP Router Interface Unit (CRIU), Channel Access Protocols (CAP's) and the net manager. The LAN side of the router (onboard the ship) utilizes the Ethernet architecture. The CRIU makes the router think it is connected via Ethernet to other routers attached to the subnet, which allows for multicasting over the broadcast RF subnets. The CRIU also handles the address resolution (Casey, 1997).

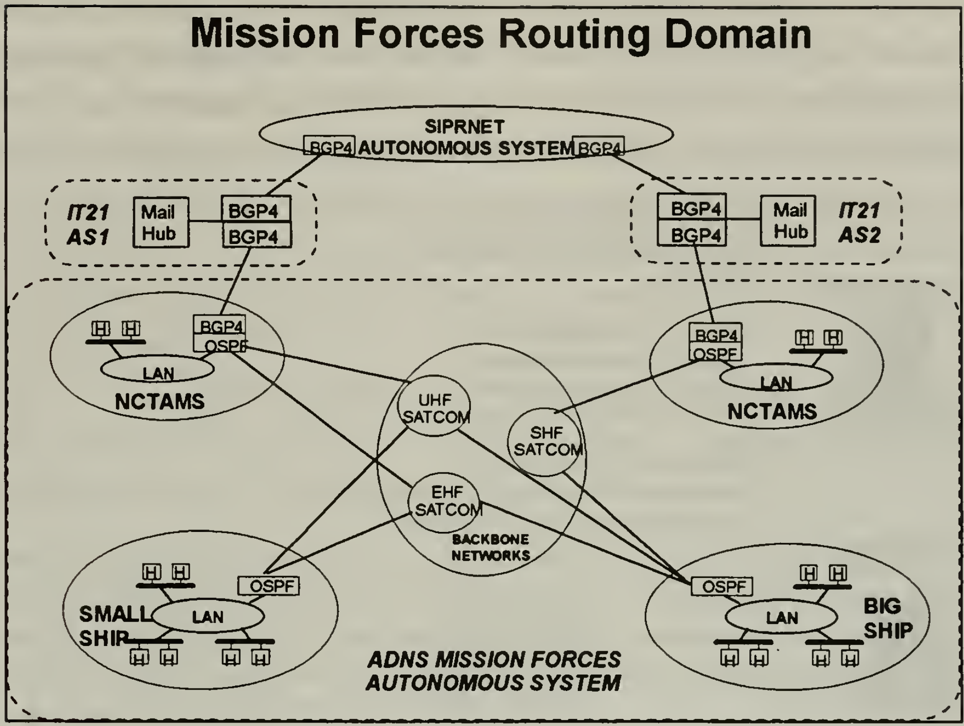

Figure 10. Generic Navy AS Architecture (Casey, 1997).

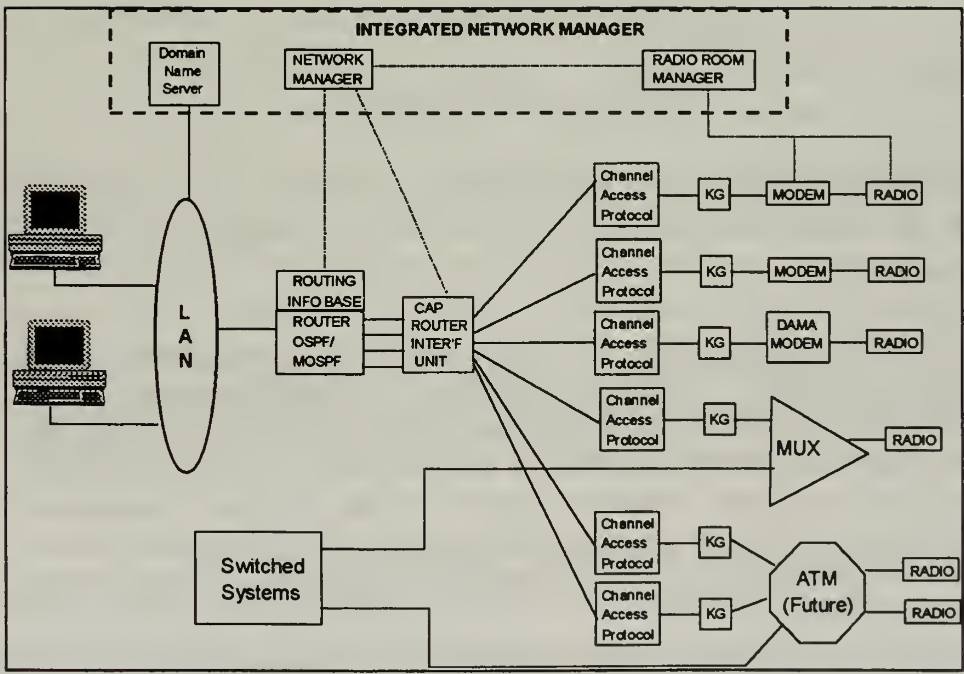

Figure 11. ADNS Node Configuration (Casey, 1997).

Most LAN computers are assigned priorities from zero to fifteen based on mission importance. The process of assignment is illustrated in Figure 12. These priorities are indicated in the packet header by the CRIU and passed to the CAP where priority queues are maintained. This priority is based solely on the packet's source port.

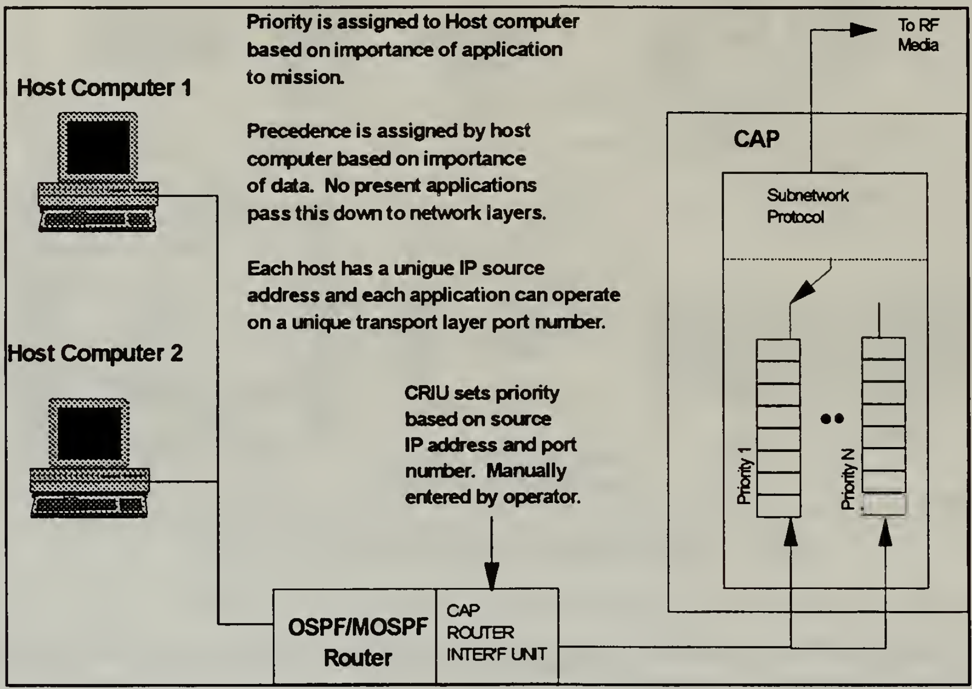

Figure 12. Priority Assignment.

The net manager sets up the priority (established and published prior to each mission) and sends it to the CRIU, although these priorities can be changes as mission objectives change (Casey, 1997).

> Priorities can also be assigned to the application (i.e. port number) within the host computer. Within an application, message precedence can be assigned, but no existing applications implement a capability for passing the precedence information down to the network layer. In addition, routers used by non-Navy networks (such as the Defense Information Infrastructure (DII) do not look at the precedence field in the IP header. The IP layer includes fields for precedence processing but applications have not used it (Casey, 1997).

Much like other protocols and architectures, ADNS provides for a priority tag at the IP (network) layer, but is currently unable to use the information. Only

the ports are prioritized within the unit's LAN (for example, the Commanding Officers' port could be given priority over the Admin division's port). These priorities determine which queue they are sent into prior to transmission. The queue threshold function applies cutoffs for the different levels of priority, and can temporarily stop data streams that are overflowing the queues. The last step in managing the network is determining and assigning routing metrics to the paths, and routing packets based on the route with the lowest value metric. An additional bandwidth management practice involves removing duplicate TCP packets as the protocol attempts to transmit its data over a relatively low bandwidth pipe (Casey, 1997).

ADNS prioritizes how data packets will be sent off the ship, both by the order transmitted and by the RF transmission path. According the Joint Maritime Communications Strategy (JMCOMS),

> Successive ADNS builds will upgrade the Navy IP routing system to provide enhanced networking features. New capabilities to be added include dynamic routing, enhanced network management, support for multicast group management, improvements in router reliability, and policy based routing (i.e., BGP4) (JMCOMS, 1997).

This indicates that ADNS is intended to take advantage of the standard protocols and architectures of the future that will provide effective multimedia data transmission QoS and bandwidth management via prioritization.

(9) Proprietary Methods. Many proprietary architectures, protocols, and tools that provide bandwidth are commercially available. Some notable recent products are 3Com's products, which provides QoS via their Priority Access Control Enabled (PACE) feature. It requires software loaded on all Ethernet adapters, and divides traffic into only two priorities–one for regular data, and one for delay sensitive traffic (Roberts, 1996). They have also created Transcendware software, which provides policy-based network management, including future implementations of 802.1p flags to prioritize application-specific data, as well as VLAN capabilities which are not included in PACE. Transcendware utilizes a policy server and allows policies to be set on a user by user basis.

Packeteer has created its Packetshaper device to control congestion by prioritizing traffic across corporate networks (Packeteer, 1997). It uses TCP/IP control mechanisms to specify the amount of bandwidth usage by a certain traffic type. It can also assign priority to traffic based on URLs, domain names, IP addresses, or

applications. The PacketShaper is primarily intended for Internet and Intranet traffic, and it identifies traffic type by its typical Internet types (ftp, email, http, etc.) (Snell, 1996).

Cisco provides bandwidth optimization across WAN links through its Internetwork Operating System (IOS). The IOS includes virtual bandwidth reservation via Custom Queuing and priority queuing via Priority Output Queuing, as well as Weighted Faire Queuing. This IOS relies on a combination of technologies already in existence–the IP protocol and the Frame Relay protocol.

> For networks that need to provide a guaranteed level of service for all traffic, Cisco offers custom queuing. Custom queuing allows a customer to reserve a percentage of bandwidth for specified protocols. Customers can define up to 10 output queues for normal data and an additional queue for system messages such as LAN keep alive messages (routing packets are not assigned to the system queue). Cisco routers service each queue sequentially, transmitting a configurable percentage of traffic on each queue before moving on to the next one. Custom Queuing guarantees that mission-critical data is always assigned a certain percentage of the bandwidth, but also assures predictable throughput for other traffic.
>
> Priority output queuing allows a network administrator to define four priorities of traffic—high, normal, medium, and low—on a given interface. As traffic comes into the router, it is assigned to one of the four output queues. Packets on the highest-priority queue are transmitted first. When that queue empties, traffic on the next highest-priority queue is transmitted, and so on. This mechanism assures that during congestion, the highest-priority data does not get delayed by lower-priority traffic. However, if the traffic sent to a given interface exceeds the bandwidth of that interface, lower-priority traffic can experience significant delays.
>
> Weighted fair queuing ensures that queues do not starve for bandwidth and that traffic gets predictable service. Low-volume traffic streams receive preferential service, transmitting their entire offered loads in a timely fashion. High-volume traffic streams share the remaining capacity, obtaining equal or proportional bandwidth. The weighting in Weighted Fair Queuing is currently affected by two mechanisms: IP precedence and Frame Relay discard eligible (DE) forward explicit congestion notification (FECN) and backward explicit congestion notification (BECN). The IP precedence field has values between 0 (the default) and 7. As the precedence value increases, the algorithm allocates more bandwidth to that conversation which allows it to transmit more frequently (Cisco, 1997a).

NetManage provides policy management through its proprietary Policy Management Architecture (PMA), which delivers a set of policy-based management services that are independent of hardware and vendors. PMA has been adopted by Ascend Communications in the form of NetManage Enhanced Windows TCP/IP ("NEWT") as of January 1997 (Silicon Valley Today, 1997).

> NetManage's PMA consists of several elements, including a data packet analyzer called the Wedge, filters that identify which traffic to act on and plug-in services that execute policies associated with specific network traffic. Plug-ins provide services such as bandwidth controls, QoS/COS signaling, security filters and encryption. PMA also defines an API so customers and third parties can define plug-ins.
>
> The Wedge is protocol-independent, Windows-based software that's installed just above the NIC driver. It identifies applications by the Windows Sockets calls they make, rather than by TCP port numbers. Once you define the policies that should apply to an endstation, the Wedge implements the policies. NetManage is leaving it up to its Original Equipment Manufacturers (OEMs) to decide how to implement policy servers and what protocol to use for communication between desktops or servers and a policy server (Petrosky, 1997).

MadgeOne is a multimedia architecture using an ATM backbone and attaches Ethernet, Token Ring, and desktop ATM to provide QoS. "MadgeOne is based on appropriate use of ATM technology, because only ATM provides guaranteed Quality of Service and low end-to-end delay that is an essential pre-requisite for effective real-time communications" (Taylor, 1996a). It is based on use of Cells In Frames (CIF) technology, which allows extension of ATM QoS to the desktop without the requirement of changing the network adapter cards.

A host of other vendors provide products that attempt to provide QoS for multimedia across LANs and WANs. Some of these companies are Digital Equipment Corporation, Cabletron Systems, Cascade Communications, Agile Networks, Ascend Communications, Nortel, Bay Networks, and Newbridge Networks. WAN-specific products are provided by Ascom, Stratacom, Northern Telecom, Ascend, Telco Communications, OnStream Networks, Xyplex, CrossCom, and Proteon. VLAN vendors include Xylan, Agile Networks, and UB Networks, along with many others.

d. *Benefits/Drawbacks of Prioritization*

Policy-based traffic management has distinct advantages and disadvantages. Realistically, advantages of using policy-based traffic management or prioritization are improved abilities to meet QoS requirements for various multimedia requirements. Theoretically, advantages would also include better use of bandwidth, more satisfied users, a decrease in network congestion problems, higher value throughput, a decrease in the pace of network upgrades, and a decrease in network infrastructure growth. These practices are expected to make network management easier and more consistent:

> Policy-based management has caught on...to make the process of coordinating corporate policies and management practice easier. 'The advantage of policies is that they ensure a consistent environment. Client/server environments that are not consistent break' (Graziano, 1996).

Any type of prioritization will require additional time and effort to install, administer, and maintain, and an MIS department may not have the economic resources (money, time or people) to supply QoS or prioritization. Additional disadvantages include the inexperience of not only the network managers, but the undeveloped market for prioritization products. The lack of standards, or the relative infancy of the recent standards will mean more headaches and more growing pains as vendors and the organizations learn to use them.

III. EMPIRICAL STUDY

A. RESEARCH FOCUS AND APPROACH

1. Research Focus

The issue of bandwidth has been an issue of concern and argument for a long time. Gilder argued in 1994 that "Bandwidth is king," and that bandwidth will increase a thousandfold over the next decade. Whether or not this is true, it has become a recognized network resource, and the treatment of bandwidth as a network resource deserves some attention. To reduce the scope of this study, the authors attempted to discover if bandwidth is being managed by chargeback or prioritization techniques only.

a. Chargeback

> For the foreseeable future, we will continue to live in a world characterized by network resource scarcity. We will move quickly towards "free" service if we use our scarce network resources–whether public or private–efficiently in economic terms. The greater the value that users receive from scarce network resources, the more they will have to invest in building better and faster networks. Meanwhile, if commercial providers are not responsive to user valuations, they will not succeed in a competitive market. The same considerations apply even to private-access networks: the ultimate goal is to maximize some human measure of the value of using the network, such as profits, sales, shareholder value, and so on (MacKie-Mason, 1996).

Mackie-Mason describes the issue of managing network resources efficiently, stating the need to optimize their use. The use of chargeback systems has the potential to address managing these resources by tracking and attaching a cost to their use, thus encouraging effective resource use and providing insight into IT costs. It does not, however, agree with his assertion that service will become free as we use the scare resources better.

Using chargeback to manage bandwidth, however, could prove to be difficult and costly. Nash discusses tracking issues in internal intranets:

> With mainframe applications, IS could figure pretty easily which users were on the system for how long. But with intranets, servers and users can be anywhere in different departments or even on different continents. Usage is tough to track, even with detailed log files. The thought of reconciling dispersed logs with accounting records is too ugly (1997).

If intranet usage within an organization is hard to track, a more complex set of network usages, including external network use, will be even harder to track.

Given the availability and flexibility of current technology, the complexity that exists within distributed computing environments makes usage-based charging a difficult solution for cost recovery or bandwidth control.

> The problem with most chargeback packages for distributed systems is that they target particular proprietary environments, such as VMS, Hewlett-Packard Co.'s HP/UX or IBM's AIX. For highly mixed environments, the current tools just aren't comprehensive enough (Karon, 1994).

Some chargeback products currently on the market include: Horizons Technology LANRecord, Intel Corp LANDesk, Express Systems Express Meter, Semantec Administrator, and Frye Computer Systems SMART. These solutions, however, are designed to work in vendor specific environments on specific platforms and not over varying diverse network structures.

It makes sense that network managers are concerned with bandwidth. Bandwidth problems provide direct feedback to them when things are not going as planned. Users complain of long delays. Subnet collision domain thresholds are exceeded. Delays occur in time sensitive traffic. "Many companies today are using expensive sniffers, Simple Network Management Protocol, protocol analyzers and remote monitoring tools to measure transactions, which create drag on the network-in terms of cost and performance" (Bendor-Samuel, 1996).

At issue is the additional use of bandwidth for accounting and chargeback purposes. This research focuses on discovering whether organizations are using available chargeback tools. And if so, how are they being used to manage bandwidth resources?

b. Prioritization

"Until recently, the ability to manage network resources and control bandwidth allocation and traffic prioritization on Ethernet network has been something network managers could only dream about" (Prodan, 1997). Networks will at some time

become congested and these organizations recognize that when this occurs certain mission-critical data transmission must receive priority. The emergence of many network architectures and protocols that provide QoS via prioritization indicates that bandwidth control can and will be achieved through prioritization.

Internal organizational issues are barriers that can affect the implementation of any new idea. Policy based management systems are not exempt.

> It's very, very difficult to implement a policy-based management system, said Jill Huntington-Lee, senior analyst with Datapro Information Services Group in Delran, N.J. Not only do you have to deal with feeding a lot of data into these systems to get started, you have to deal with a lot of internal company issues (Graziano, 1996).

In addition, some analysts regard the technology's inherent complexity to difficult to implement in some organizations (Graziano, 1996).

One exception to this is the Navy's research effort and prototype installation of ADNS. Established routing priorities within the autonomous systems have been determined based on mission objectives. However, these routing priorities deal only with the port where a particular device is attached, and it is difficult to rapidly adapt these priorities as mission needs change. The system is also a proprietary stove-pipe system since the Navy built it from the ground up.

> Vendors participating in the roundtable agreed there exists a need for more use of policy-based management. But that it requires a form of embedded intelligence in management product and managed devices that, for the most part, doesn't yet exist (Bruno, 1997).

The Navy is not the only organization that has recognized the changes in internetworking. According to 3Com, the nature of network management is changing:

> There are several important changes taking place. First, more and more businesses are deploying Internet/Intranet technologies, and the distributed nature of these any-to-any computing models results in unpredictable traffic flows. Second, we are also seeing the emergence of a new class of business applications (multimedia, collaborative workgroups, etc.) which require more bandwidth and less latency. Third, more and more companies recognize the strategic value of the network and are trying to align network operations to support key business objectives.

Given these trends, it is important that customers be able to deliver the appropriate class and quality of network services required to maintain business productivity. This means that customers must have greater control over the network and must be able to establish network user, application, and security policies and priorities that support strategic business policies (3Com, 1997).

According to many literary sources, policy-based management is needed and is becoming a reality:

- Many other vendors now agree that building an integrated LAN requires more than pure bandwidth. What's needed, they say, is a way to prioritize multimedia traffic–and the vast majority of the LAN switches have no such prioritization mechanism (Roberts, 1996).

- "Bandwidth has clearly been leading [as a congestion solution], but other things have been lacking...[such as] policies and rules about the network, who can do what on the network and the flexibility of the network" (Kalin, 1997).

- "Policy-based management may seem like a futuristic prospect, but it's closing in on reality" (Graziano, 1996).

- Until recently, the ability to manage network resources and control bandwidth allocation and traffic prioritization on Ethernet network has been something network managers could only dream about. But with policy-based quality of service (QoS), the dream becomes a reality. Policy-based QoS allows a network manager to allocate bandwidth and prioritize traffic within the network based on a set of administrative policies and usage patterns (Prodan, 1997).

- "As traditional internetworks evolve into multiservice networks supporting voice, video, and other bandwidth- and delay-sensitive application, policy-based routing will increase in importance" (Decisys, 1996).

- A better approach [to network management] involves building a network that can harness bandwidth as needed and can control delay. Though today's open networking protocols have allowed users to run whatever applications they like, the protocols have also effectively turned the network into a dumb pipe. The goal now is to make the pipe smarter. "Throwing bandwidth at every problem is inappropriate," says Mary Petrosky, an analyst with the Burton Group consulting firm in San Mateo, Calif. "Instead, the question should be: What do you want the network to do?"(Janah, 1996).

QoS and prioritization for internetworking does not appear to involve questions of "if" it will be developed and implemented globally, but simply questions of "how" and "when." Considering all these assertions, the authors expect to find that organizations are using some form of policy-based management using prioritization.

2. Research Approach

The approach used in this thesis consists of the following:

•Conduct a literature search of books, magazine articles, CD-ROM systems, Internet literature, and other library information services describing network management techniques.

•Consult network managers in academic institutions on current and proposed techniques and tools used to manage their LAN bandwidth.

•Consult network managers in military institutions on current and proposed techniques and tools used to manage their LAN bandwidth.

•Consult network managers in the business sector on current and proposed techniques and tools used to manage their LAN bandwidth.

•Consider application of current network management discoveries to DOD.

After conducting an extensive literature and cyberspace search, a myriad of bandwidth management architectures and protocols were uncovered and are discussed as background in Chapter II. This discovery led to pursuit of a purely exploratory analysis vice an experimental analysis. The research interest was in discovering whether organizations were using any of the management tools found. As a result, the research was open-ended, broadly based, and did not purport to prove or disprove any experimental models.

B. SAMPLING

A nonprobability sampling method was used to obtain a sample composed of network management professionals from academic, military, and commercial organizations. A probability sampling design was avoided due to cost and time constraints as well as the non-availability of the total population to the researchers. A primary intent of the research was to obtain a range of available management technologies in use and not to generalize this to a population parameter.

In an attempt to increase the accuracy of the sample, a purposive sampling method was used. This method chosen was judgment sampling in order to specify the criteria to whom the survey instrument was administered. Initially 425 organizations were queried, while a total sample of 181 network management professionals were actually administered the survey instrument.

1. Academic Institutions

Colleges and Universities were selected due to their experience in operating developed computer networks central to their core organizational processes. Schools were chosen from the University of Florida College of Liberal Arts & Sciences web page listing American colleges and universities (http://www.clas.ufl.edu/CLAS/american-universities.html). School web pages were searched for the school's MIS/network management office in order to find a potential point of contact.

2. Military Installations

Military installations and organizations were intended to provide data about military distributed computing networks. Army installations were chosen from the US Army Installations online web page listing of Army commands and installations (URL: http://www.army.mil/cfdocs/s_installation.cfm). Air Force Installations were chosen from the Air Force Sites web page listing of Air Force commands and installations (URL: http://www.af.mil/sites/). Navy Installations were chosen from the Navy Online web page listing of Navy commands and installations (URL: http://www.ncts.navy.mil/cgi-bin/sites.pl?-alpha). Marine Corps Installations were chosen from the US Marine Forces Pacific Marine Corps Locations Around the World web page listing Marine Corps commands and installations (http://www.mfp.usmc.mil/othmcsit.htm). Each web site was

researched for Department of Information Technology, MIS, or similar offices in order to find the best candidate(s) to survey.

3. Commercial Organizations

Commercial organizations were researched as well, to provide a snapshot of corporate network management techniques. An analysis of this type is integral to any research on network management, especially in light of the Clinger-Cohen Act of 1996, which requires that all government agencies use best business practices in IT acquisitions. Since the intend is to apply this research to DOD agencies, omitting large businesses would leave a gap in an otherwise comprehensive evaluation of network management practices. Organizations were chosen from the Fortune 500 list of companies (http://www.pathfinder.com/@@MqumIAYAZfCb8tb*/fortune/fortune500/). Web sites were searched for a potential point of contact and webmaster.

C. DESIGN AND DATA COLLECTION

The design of this research was simply an ex post facto study to test the hypothesis that a majority of academic, military, and commercial organizations use prioritization (policy-based traffic management) and/or chargeback policies to manage their distributed computing networks. The research intended to test this hypothesis, and to discover details about the organizations who were using prioritization and/or chargeback management tools. The decision to administer an electronic mail survey was made due to the availability of contact resources on the Internet, the ease of administration, and the cost savings involved with using the Internet as a distribution platform.

The data collection for this thesis began with a literature search of books, magazine articles, CD-ROM systems, Internet literature, and other library information services describing network management techniques. The main source of information was found in Internet literature and online Information Technology journals and magazines, due to a lack of information regarding prioritization and/or chargeback mechanisms in books, CD-ROM systems, and library information sources. Although there was information available on mainframe computing chargeback techniques, no distributed computing chargeback data available in the traditional research literature was found. Internet searches were focused on policy-based network management, chargeback, and prioritization. Network management products were researched extensively prior to

execution of the survey instrument, verifying that there are indeed products and technologies available for chargeback, prioritization, and policy-based network management.

Data collection was initiated by contacting network managers at each organization via electronic mail (email). Email was sent to the organization's webmaster or to a staff member identified as a member of the administrative Management Information Systems/Information Technology department or equivalent. This was done in order to identify individuals who could accurately complete the survey instrument. After contacting the appropriate personnel at each organization contacted, the survey instrument was administered via email.

Table 2 shows the number of installations contacted, the number of surveys administered, and the number of responses received via email from each organization contacted.

Table 2. Organizations Contacted.

Installation	Number Contacted	Survey Administered	Responses Received
Air Force	82	40	30
Army	42	18	10
Marine Corps	17	3	2
Navy	36	21	15
Academic Inst.	103	65	52
Companies	145	34	12
Total	**425**	**181**	**121**

It should be noted that company web sites provided much less information than either military or academic web sites. Due to a lack of contact information combined with expected company policies that regard computer network information as proprietary, it was anticipated that fewer companies would be contacted and fewer companies would respond (than military or academic organizations). As a result of non-response and fewer electronic mail contacts in the public domain, telephone interviews were attempted with 22 of these companies resulting in one additional survey being administered.

In all cases, if initial email received no response within approximately four weeks, a second attempt was made to contact personnel or organizations via email.

D. SURVEY INSTRUMENT

Although an extensive Internet search was conducted to determine what network management technologies existed, an exhaustive predetermined set of categories was not obtained. Consequently, the survey consisted of four open-ended questions. A copy of the survey sent is located in Appendix A, along with copies of typical correspondence sent. Four questions were asked:

1. How would you classify your organization's LAN/WAN network? (ATM, Ethernet, Fast Ethernet, FDDI, or combination–PLEASE CLARIFY IF COMBINATION)

2. Does your organization prioritize network traffic and/or network access?

3. If so, how is it prioritized? (By application, user, data origin, data destination, first come-first served, IP address, etc.)

PLEASE DESCRIBE.

4. Does your organization charge users for network resources? (By time, transaction, application, network connection, connection speed, etc.)

PLEASE DESCRIBE.

Respondents were asked to send an email reply to the survey with answers to these questions. A more sophisticated survey instrument was not designed since the intention was to follow up on affirmative responses with additional questions via email or a personal telephone interview.

E. ANALYSIS STRATEGY

The first phase of the analysis strategy was to determine the existence of prioritization and chargeback management tools or products using Internet sources. This step required little data analysis, but required an extensive effort to develop a taxonomy of familiar network architectures, common chargeback and prioritization methods, and emerging chargeback and prioritization technologies.

Survey strategy included pinpointing exact network management practices, policies, and procedures after obtaining an initial, less detailed email responses. Data analysis was to include nonparametric statistical analysis on the information obtained via the survey instrument and follow-up interviews with network management professionals. Analysis was to include testing the descriptive hypotheses, determining variable frequencies, and investigating some variable relationships. All data obtained via the survey instruments was to be treated as nominal data. Test performed were to include binomial and chi-squared tests.

All cases were to be analyzed as a single sample, then data collected from academic, military, and corporate organizations were broken out as samples to provide further granularity.

IV. FINDINGS

A. RESPONSE DEMOGRAPHICS

1. Organizations

The survey instrument was administered to 181 network managers, and a total of 121 responded to the survey. The response rate was 66.85%, which was surprisingly high. Responses are shown in Figure 13, and are segmented by institution type.

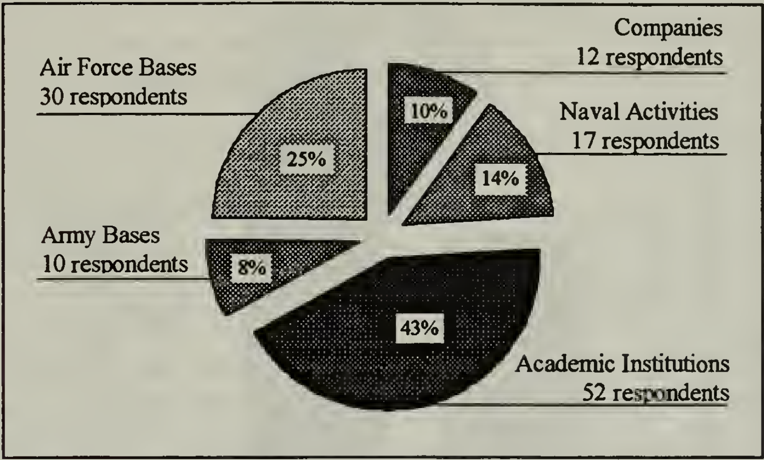

Figure 13. Respondents Classified by Institution.

Another view of the respondent data is shown in Figure 14 in which data is presented by organization type. Responses included 9.9% (12) from companies, 47.1% (57) from military installations, and 43.0% (52) from academic institutions. As expected, companies provided the least amount of information, and had the highest non-response rate (76%). The large non-response rate from companies is attributed to the lack of contact information available to the researchers and several company policies which regard network information as proprietary.

Figure 15 provides a view of the response data by segmenting the data between military and non-military organizations. Responses include 47.1% (57) from military and 52.9% (64) from non-military organizations.

Figure 16 provides a view of the response data by segmenting the data by military service. The two Marine Corps responses have been included in the Naval category.

Responses include 29.8% (17) from Naval installations, 17.5% (10) from Army installations, and 52.6% (30) from Air Force installations.

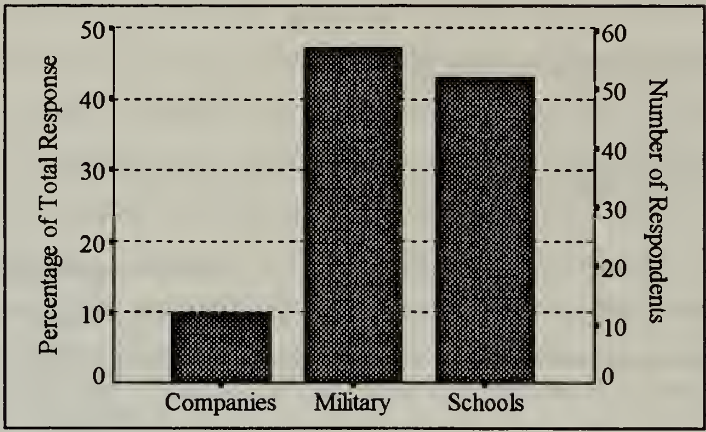

Figure 14. Respondents Classified by Organization.

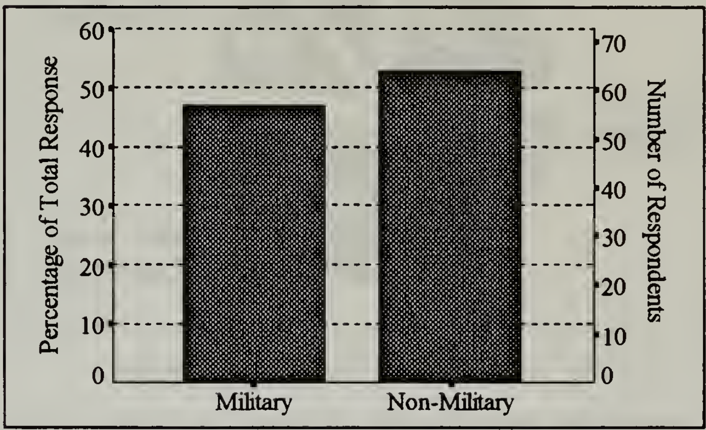

Figure 15. Military and Non-Military Respondents.

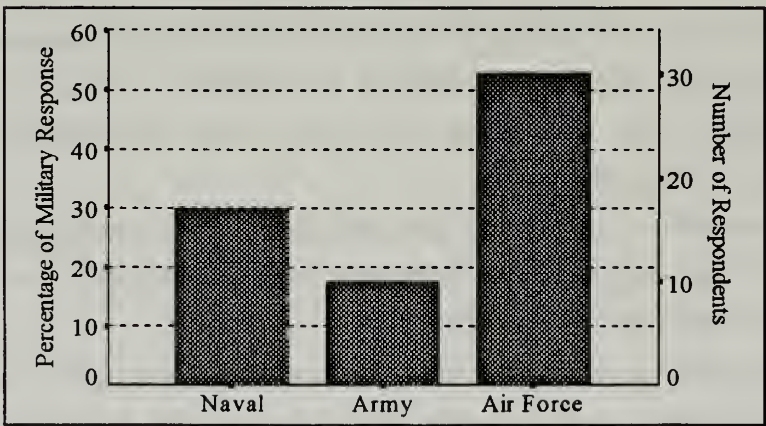

Figure 16. Respondents Classified by Service.

2. Networks

The survey instrument elicited responses from organizations to identify their network architecture. Responses included: Ethernet, Fast Ethernet, FDDI, Token Ring, and combination. The reported frequency counts and percentages of network types for all organizations surveyed is shown in Figure 17 below.

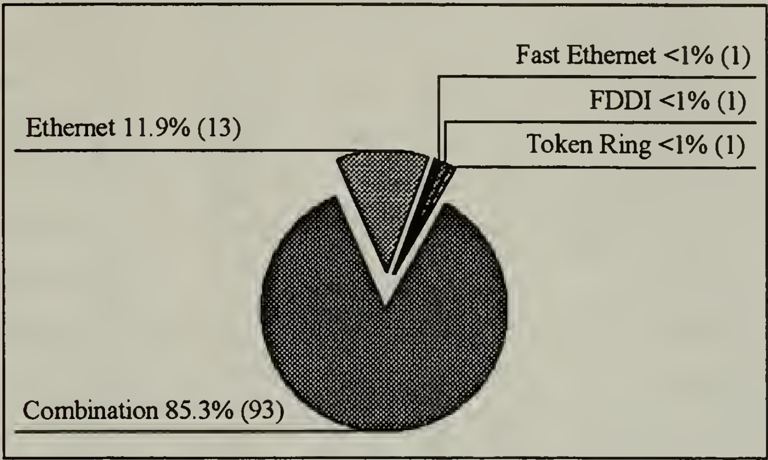

Figure 17. Organization Network Type Frequencies.

Responses across all organization types are dominated by combination networks with percentages equal to 87.5%, 84.9% and 85.4% for companies, military installations, and educational institutions respectively. A graphical view of this network response data is shown in Figure 18 in which data is segmented by organization type.

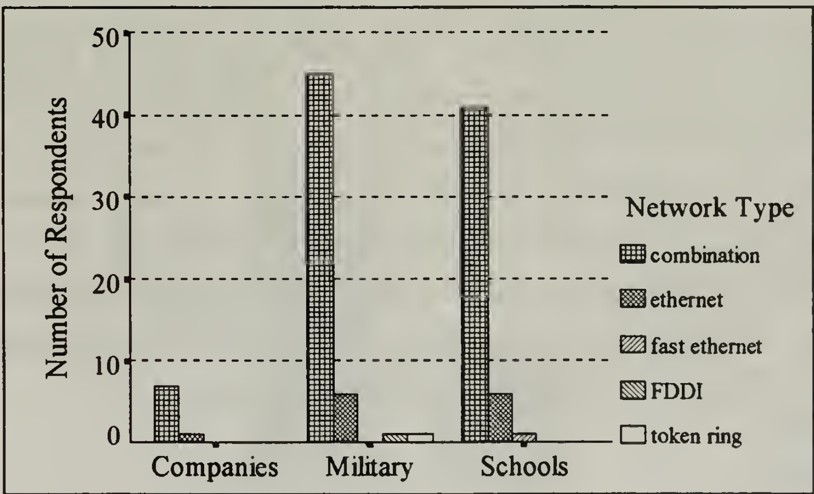

Figure 18. Network Architectures by Organization.

Table 3 below provides additional insight into the makeup of combination networks for all organizations surveyed. Included in the table are frequencies for all network architecture responses received.

Table 3. Network Architecture Response Frequencies.

Category label	Count	% of Responses
Ethernet	97	30.7
Fast Ethernet	60	19.0
FDDI	65	20.6
ATM	33	10.4
Token Ring	15	4.7
Frame Relay	7	2.2
SONET	2	.6
X.25	1	.3
ISDN	1	.3
Serial	32	10.1
Local talk	3	.9

B. CHARGEBACK FINDINGS

1. Overview

Since there were no indications of chargeback use prior to administering the survey instrument, the hypothesis that a majority of organizations use some form of chargeback to manage their network resources was adopted. This section summarizes the data that refutes this expectation, by providing survey results received from all organizations relating to chargeback mechanisms. Organizations were included in calculations provided they indicated use or non-use of chargeback mechanisms in their survey responses. For the purpose of additional analysis, the following items/resources were included as categories for chargeback mechanisms in place:

- Bandwidth
- Initial access
- Network access
- Connection upgrade

•Remote access

•Overhead

•Disk storage

These categories were created directly from the survey results and network managers were individually contacted to obtain clarification of the categories reported. Bandwidth was based on data transfer capability (Kbps, Mbps). Initial access was described as a one time network access installation fee. Network access was described as a recurring network access fee. Connection upgrade was described as an installation fee to increase data transfer capability. Remote access was essentially a fee for remote network access connectivity capability. Overhead was referred to as an administrative fee for items not included in other categories. Disk storage was identified as a fee based on storage capacity available.

Although attempts were made to obtain information from each organization in this regard, not all data was obtained. Consequently, percentages indicated are valid percentages of actual data obtained unless otherwise indicated. Missing data is not included in percentage calculations. Several graphical representations of the data are provided for comparison across all organizational categories as well as across functional organizational categories.

2. Overall Usage/Non-usage of Chargeback mechanisms

Use of chargeback mechanisms across all organizations surveyed is shown in Figure 19. Of the valid cases (n=120), 30% (36) of the organizations surveyed indicated they use of some form of chargeback.

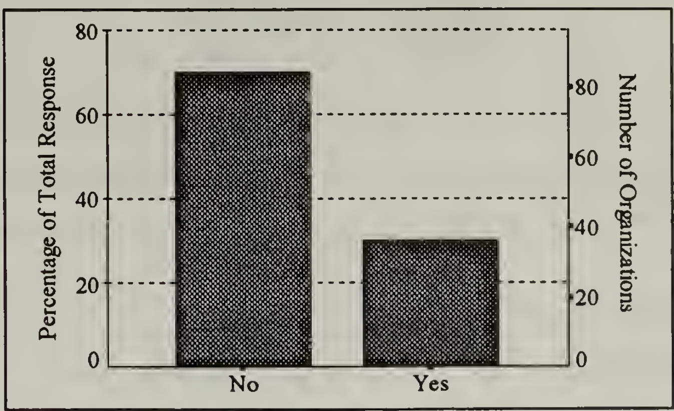

Figure 19. Use of Chargeback Mechanisms Across Organizations.

Figure 20 shows the percentages of chargeback mechanisms in use by organization types relative to one another. Of the valid cases (n=36), 16.7% (6) were companies, 16.7% (6) were military installations, and 66.7% (24) were academic institutions.

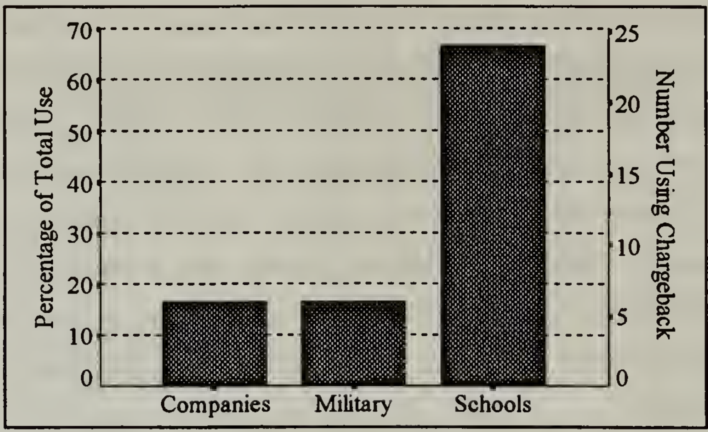

Figure 20. Chargeback Use by Organizations.

Figure 21 provides a view of the data by segmenting the data between military and non-military organizations. Non-military organizations account for 83.3% (30) of the total organizations using some form of chargeback mechanisms.

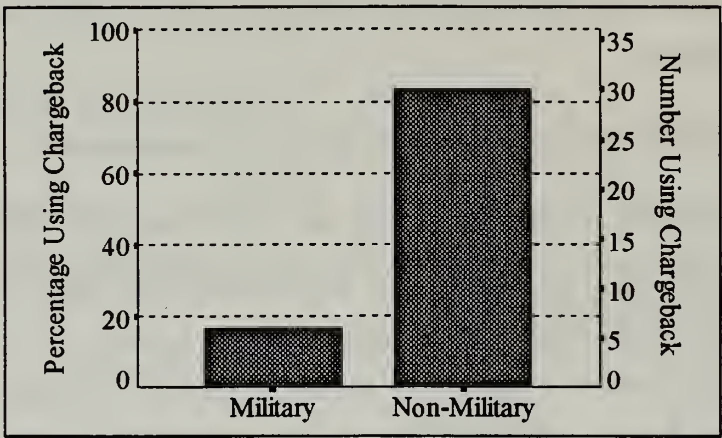

Figure 21. Chargeback Use by Military and Non-Military Organizations.

Additional display of granular data relative to military service is not provided due to the small number of valid military cases (n=6) that indicated use of chargeback mechanisms.

Table 4 provides the breakdown of items/resources charged for across all organizations. Initial network access and continued network access account for 68% of all responses received. Only one organization indicated that a chargeback mechanism was in place that utilized bandwidth as a unit of measure for cost recovery.

Table 4. Resources Charged for Across Organizations.

Category label	Count	% of Responses
Bandwidth	1	2.0
Initial Network Access	15	30.0
Continued Network Access	19	38.0
Connection Upgrade	4	8.0
Remote Access	6	12.0
Overhead	2	4.0
Disk Storage	1	2.0
All Resources	2	4.0

Table 5 provides a breakdown of how these charges were determined/applied across all organizations surveyed which used chargeback methods. For clarification, reimbursement for cost is based on actual cost of network services administered (typically for hardware installations); flat rate fee is a periodic non usage based fee for all service; tiered rate fee involves different pricing structures based on capability or service received; volume capacity is based on dedicated bandwidth availability; percentage by user is essentially division of all network costs evenly to all users (regardless of usage); and time based usage charges base on the length of time connected to network resources. The flat rate fee cost recovery method accounted for 63.3% of all methods reported on the survey.

Table 5. Methods of Cost Recovery Across Organizations.

Category Label	Count	% of Responses
Reimbursement of Cost	9	18.4
Flat Rate Fee	31	63.3
Tiered Rate Fee	3	6.1
Volume Capacity	1	2.0
Percentage by User	2	4.1
Time based Usage	3	6.1

3. Academic Institutions

Use of chargeback mechanisms within academic institutions surveyed is shown in Figure 22. Of the valid cases (n=52), 46.2% (24) of the academic institutions surveyed use some form of chargeback. 80.5% of all resources charged were for initial and continued network access. Additionally, the cost recovery method most used was a flat rate fee which accounted for 77.8% of the responses.

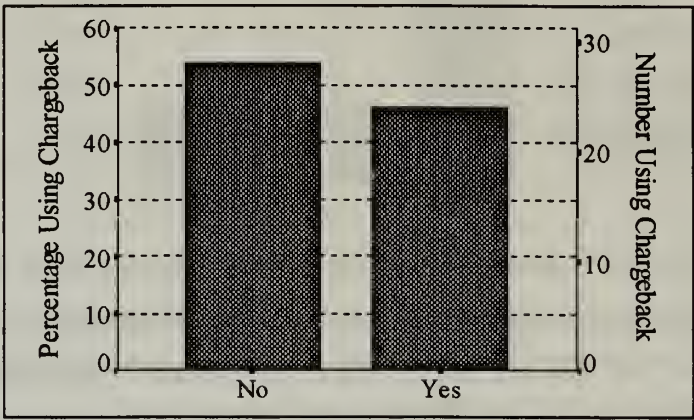

Figure 22. Chargeback Use by Academic Institutions.

4. Military Organizations

Use of chargeback mechanisms within military organizations surveyed is shown in Figure 23. Of the valid cases (n=57), 10.5% of the military organizations surveyed use some form of chargeback. 71.5% of all resources charged were for initial network access and connection upgrade. Additionally, the cost recovery method most used was

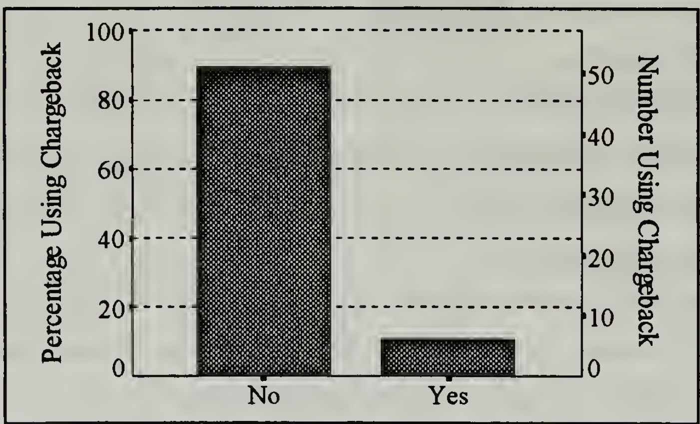

Figure 23. Chargeback Use by Military Organizations.

reimbursement for cost as expected. This accounted for 85.7% of the responses. Although these percentages are included for completeness, it should be noted that only 6 military organizations surveyed indicated the use of chargeback mechanisms. As a result, variation in such a small data set could be misleading.

5. Corporations

Use of chargeback mechanisms within companies surveyed is shown in Figure 24. Of the valid cases (n=11), 54.5% (6) of the companies surveyed use some form of chargeback. 57.2% of all resources charged were for continued network access and remote access. Additionally, the cost recovery method most used was a flat rate fee which accounted for 33.3% of the responses. Again, although these percentages are included for completeness, it should be noted that only 6 companies surveyed indicated the use of chargeback mechanisms. A small data set such as this could be a misleading indicator of chargeback usage.

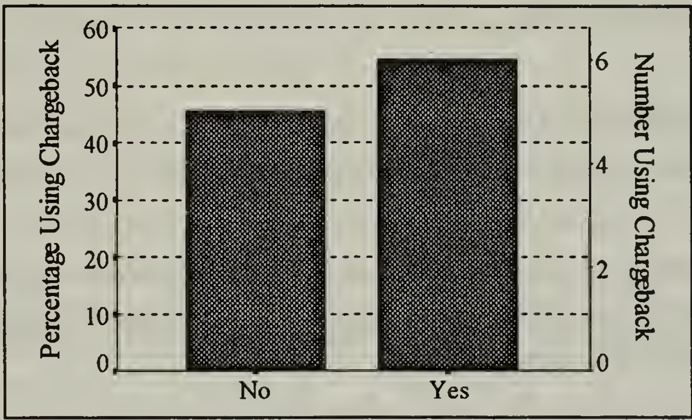

Figure 24. Chargeback Use in Companies.

6. Hypothesis Testing and Relationships

This section contains the results of hypotheses tested as they relate to chargeback mechanisms in all organizations surveyed. It also includes the results of investigation into relationships of some variables of interest. Although no generalization can be made to population parameters due to the non-probabilistic sampling method used, the results are still of interest in our investigation. Appendix B contains the binomial tests results for the

hypothesis tests of the primary research questions as discussed in the introduction. The statistical package SPSS version 6.1.2 was used for all calculations.

The binomial test results from the descriptive hypothesis are summarized in Table 6. In all tables, "n" indicates the sample size/number of cases.

Table 6. Primary Chargeback Research Hypothesis Test Results.

Null Hypothesis	Result	n	1-Tailed P value
H_o: 51% of all Organizations use chargeback mechanisms.	Reject H_o	120	.0000
H_o: 51% of Companies use chargeback mechanisms.	Fail to Reject H_o	11	.5271
H_o: 51% of Military installations use chargeback mechanisms.	Reject H_o	57	.0000
H_o: 51% of Academic institutions use chargeback mechanisms.	Fail to Reject H_o	52	.2876

Further hypothesis tests were performed using chi-squared tests to investigate the relationships between organizations and chargeback mechanisms in place. The results are contained in Table 7. Statistical printouts are contained in Appendix C. Expected values used in chi-squared tests are based on percentages equivalent to the response rates received from each organization. This was necessary due to the differing number of responses received from each organization.

Other hypothesis testing was performed to investigate relationships between network architecture and chargeback mechanisms in place. A summary of results is provided in Table 8. Statistical printouts are also contained in Appendix C. Due to the low reported use of chargeback mechanisms, and the large percentage of "combination network" responses, insufficient data for chi-squared analysis resulted at organizational levels other than Schools. This same data characteristic affected hypothesis testing between individual network types and chargeback. The investigation between Ethernet architectures and chargeback was the only hypothesis that provided sufficient data for chi-squared analysis.

Table 7. Additional Chargeback/Organization Hypothesis Test Results.

Null Hypothesis	Result	n	Significance
H_o: The use of chargeback mechanisms is independent of the organization. (Companies, Military, Schools)	Insufficient Data	36	N/A
H_o: Non-use of chargeback mechanisms is independent of the organization. (Companies, Military, Schools)	Reject H_o	84	.0397
H_o: The use of chargeback mechanisms is independent of the type of organization. (Military, Non-Military)	Reject H_o	36	.0003
H_o: The use of chargeback mechanisms is independent of military installation. (Naval, Army, Air Force)	Insufficient Data	6	N/A
H_o: Non-use of chargeback mechanisms is independent of military installation. (Naval, Army, Air Force)	Fail to Reject H_o	51	.9328

Table 8. Additional Chargeback/Network Architecture Hypothesis Test Results.

Null Hypothesis	Result	n	Significance
H_o: The use of chargeback mechanisms is independent of network type.	Reject H_o	34	.0000
H_o: The use of chargeback mechanisms is independent of network type for schools.	Reject H_o	23	.0000
H_o: Non-use of chargeback mechanisms is independent of organizations using Ethernet.	Reject H_o	72	.0380

Investigation of correlation between organization type, network architectures, and use of chargeback mechanisms was determined using cross tabulation. Appendix D contains complete results for each correlation tested. The results are summarized in Table 9. Note that a significance greater that .05 indicates no

association exists between the variables tested.

Table 9. Correlation Test Results for Chargeback/Organizations/Networks.

Association Tested	Phi/Cramer's V	n	Significance
Use of chargeback mechanisms and the organization. (Companies, Military, Schools)	.40733	120	.00005
Use of chargeback mechanisms and the type of organization. (Military, Non-Military)	.40421	120	.0001
Use of chargeback mechanisms and type of military installation. (Naval, Army, Air Force)	.15396	57	.50889
Use of chargeback mechanisms and the type of network architecture.	.25171	109	.14095
Type of network architecture and the organization. (Companies, Military, Schools)	.12528	109	.90521

C. PRIORITIZATION FINDINGS

1. Overview

As with chargeback, since there were no indications of prioritization use before administering the survey instrument, the hypothesis that a majority of organizations (51%) use some form of prioritization mechanism to manage their network resources was adopted. This section summarizes the data that refutes this expectation, by providing survey results received from all organizations relating to prioritization schemes in place. Organizations were included in calculations provided they indicated use or non-use of prioritization schemes in their survey responses. For the purpose of additional analysis, the following items/resources were included as categories for prioritization methods in place:

- Bandwidth
- Initial access
- Network access
- Restoration of connection
- Electronic mail.

These categories were created directly from the survey results and network managers were individually contacted to obtain clarification of the categories reported. Initial access was identified as a method for prioritizing initial connectivity to users of the network. Network access was described as the method in place to control access to network resources after initial connectivity was established. Restoration of connection was described as the policy in place which dictates the order in which assets be restored in the event the network is disabled. The category of electronic mail essentially focused on who was allowed access to network mail applications.

Although attempts were made to obtain information from each organization in this regard, not all data was obtained. Consequently, percentages indicated are valid percentages of actual data obtained unless otherwise indicated. No missing data is included in percentage calculations. Several graphical representations of the data are provided for comparison across all organizational categories as well as across functional organizational categories.

2. Overall Usage/Non-usage of Prioritization

Use of prioritization schemes across all organizations surveyed is shown in Figure 25. Of the valid cases (n=116), 12.9% (15) of the organizations surveyed indicated they use some form of prioritization.

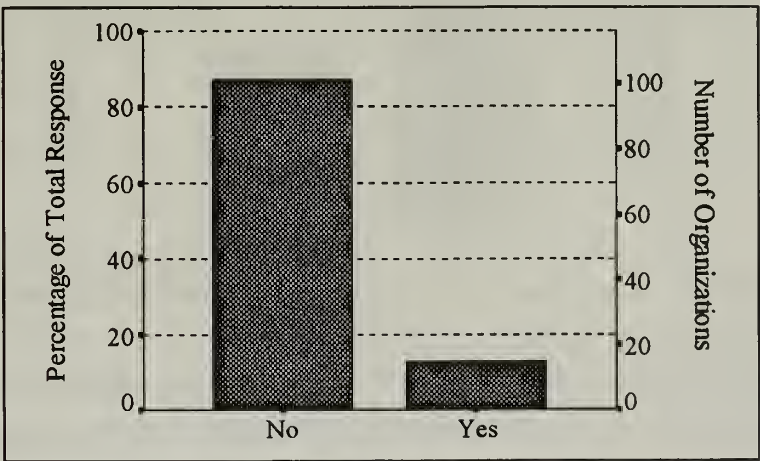

Figure 25. Use of Prioritization Schemes Across Organizations.

Figure 26 shows the percentages of prioritization schemes in use by organization types relative to one another. Of the valid cases (n=15), 20.0% were companies, 66.7% (10) were military installations, and 13.3% (2) were academic institutions.

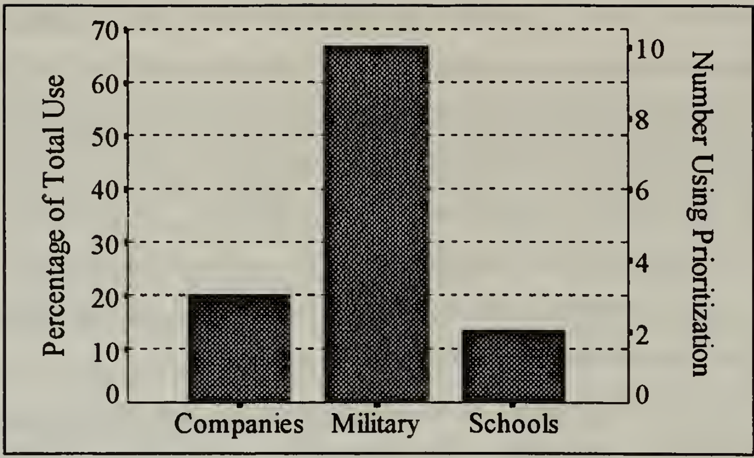

Figure 26. Prioritization Use by Organizations.

Figure 27 provides a view of the data by segmenting the data between military and non-military organizations. Military organizations account for 66.7% (10), and non-military for 33.3% (15) of the total organizations using some form of prioritization. Although percentages are included for completeness, the small prioritization sample sizes yield variations among the organizations that should be viewed with caution.

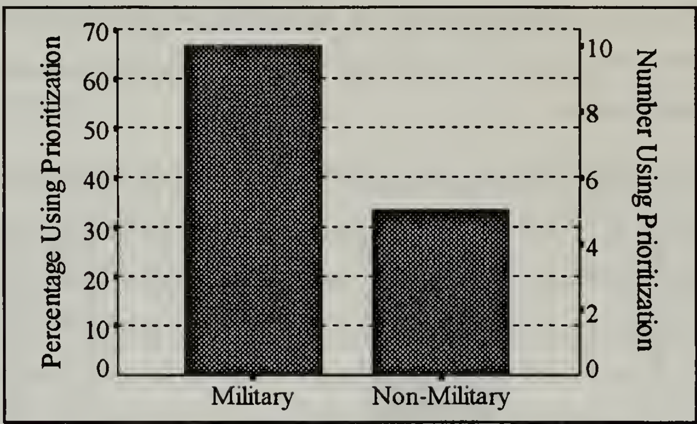

Figure 27. Prioritization Use by Military and Non-Military Organizations.

Additional display of granular data relative to military service is not provided due to the small number of valid military cases (n=10) that indicated use of prioritization schemes.

Table 10 provides the breakdown of resource prioritization across all organizations surveyed. Resource categories indicated were derived directly from the survey instrument responses. Prioritizing bandwidth accounted for 60.0% of all responses received.

Combined with initial access as a response, they made up for 80.0% of all responses received.

Table 10. Resources Prioritized Across Organizations.

Category label	Count	% of Responses
Bandwidth	9	60.0
Initial Network Access	3	20.0
Network Access	1	6.7
Restoration of Connection	1	6.7
Electronic Mail	1	6.7

Traditional prioritization methodologies focus on obtaining access to some network resource, not on physical/security access to the network which was included by some respondents. This thesis will focus on bandwidth prioritization only. Table 11 below provides the breakdown of responses that indicate bandwidth prioritization practices. For clarification, volume is based on bandwidth required/used and location identifies the methods in place to control access based on physical location of network equipment.

Table 11. Bandwidth Priority Method Used.

Category label	Count	% of Responses
Data Type/ Application	7	77.8
Volume	1	11.1
Location	1	11.1

3. Academic Institutions

Use of prioritization schemes within academic institutions surveyed is shown in Figure 28. Of the valid cases (n=52), only 3.8% (2) of the academic institutions surveyed reported use of prioritization. The priority methods used were based on volume and the resource prioritized was bandwidth for both cases.

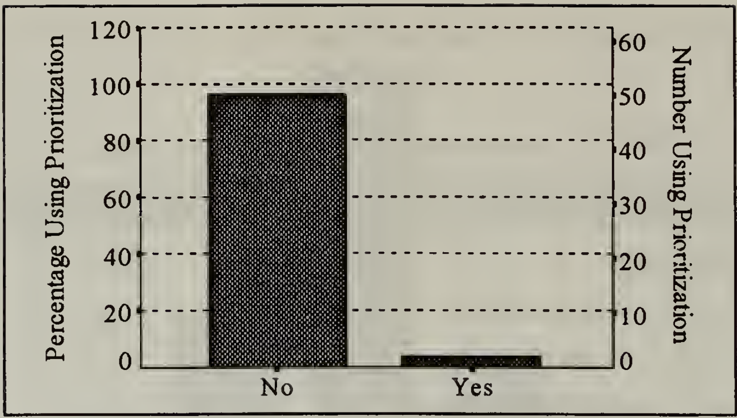

Figure 28. Prioritization Use by Academic Institutions.

4. Military Organizations

Use of prioritization within military organizations surveyed is shown in Figure 29. Of the valid cases (n=55), only 18.2% (10) of the military organizations surveyed reported the use of prioritization. 55.6% of all prioritization methods were by application. Additionally, bandwidth and initial access account for 70% of resources prioritized.

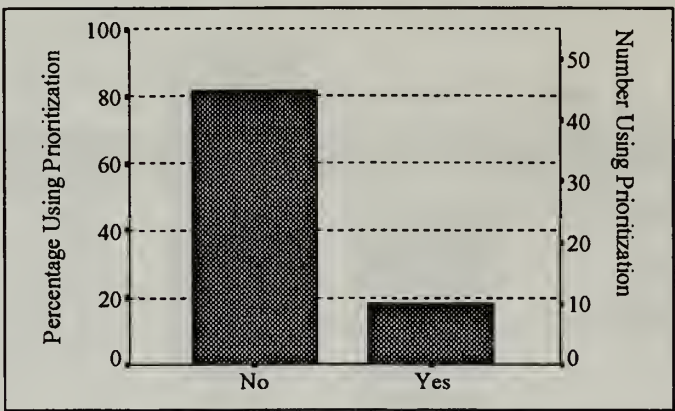

Figure 29. Prioritization Use by Military Organizations.

5. Corporations

Use of prioritization schemes within companies surveyed is shown in Figure 30. Of the valid cases (n=9), 33.3% (3) of the companies surveyed use some form of chargeback. 50.0% of all prioritization methods reported were by data type. Additionally, the only resource prioritized was bandwidth for all cases reported. These percentages are included for completeness despite the small sample size obtained.

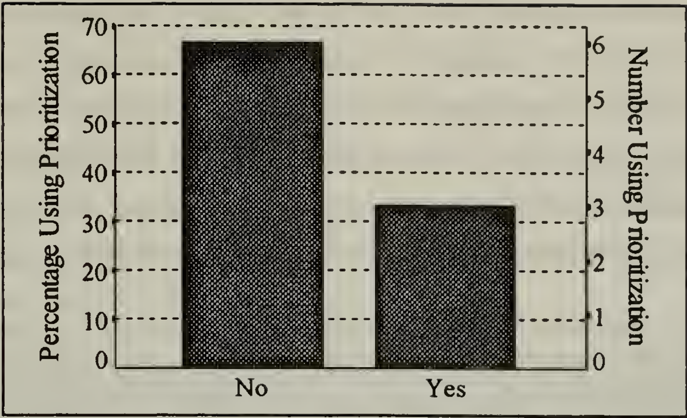

Figure 30. Prioritization Use in Companies.

6. Hypothesis Testing and Relationships

This section contains the results of hypotheses tested as they relate to prioritization schemes used in all organizations surveyed. It also includes the results of investigation into relationships of some variables of interest. Although no generalization can be made to population parameters due to the non-probabilistic sampling method used, the results are still of interest in our investigation.

Appendix B contains the binomial tests results for the hypothesis tests of the primary research questions as discussed in the introduction. The statistical package SPSS version 6.1.2 was used for all calculations. The binomial test results from the descriptive hypothesis are summarized in Table 12. In all tables, "n" indicates the sample size/number of cases.

Table 12. Primary Prioritization Hypothesis Test Results.

Null Hypothesis	Result	n	1-Tailed P value
H_o: 51% of all Organizations use prioritization schemes	Reject H_o	116	.0000
H_o: 51% of Companies use prioritization schemes	Fail to Reject H_o	9	.2346
H_o: 51% of Military installations use prioritization schemes	Reject H_o	55	.0000
H_o: 51% of Academic institutions use prioritization schemes	Reject H_o	52	.0000

Further hypothesis tests were performed using chi-squared techniques that investigate the relationships between organizations, network architectures, and prioritization. The results are contained in Table 13. Statistical printouts for chi-squared results are contained in Appendix C. Expected values used in chi-squared tests are based on percentages equivalent to the response rates received from each organization. This was necessary due to the differing number of responses received from each organization.

Table 13. Additional Prioritization/Organization Hypothesis Test Results.

Null Hypothesis	Result	n	Significance
H_o: The use of prioritization schemes is independent of the organization. (Companies, Military, Schools)	Insufficient data	15	N/A
H_o: Non-use of prioritization schemes is independent of the organization. (Companies, Military, Schools)	Fail to Reject H_o	101	.2551
H_o: The use of prioritization schemes is independent of the type of organization. (Military, Non-Military)	Fail to Reject H_o	15	.1290
H_o: The use of prioritization schemes is independent of military installation (Naval, Army, Air Force)	Insufficient Data	10	N/A
H_o: Non-use of prioritization schemes is independent of military installation (Naval, Army, Air Force)	Fail to Reject H_o	45	.8588
H_o: The use of prioritization schemes is independent of network type	Reject H_o	15	.0008

Other hypothesis testing was attempted to investigate relationships between network architecture and prioritization schemes in place. Due to the low reported use of prioritization mechanisms across all organizations, insufficient data resulted in chi-squared analysis at the granularity of organizational level and below (Companies, Military, Schools). This same data characteristic prevented all chi-squared hypothesis testing

between individual network types and prioritization. Consequently, only one hypothesis was tested between network architecture and prioritization.

Investigation of correlation between organization type, network architectures, and use of prioritization schemes was determined using cross tabulations. Appendix D contains complete results for each correlation tested as it relates to prioritization. The results are summarized in Table 14. Note that a significance greater than .05 indicates no association exists between the variables tested.

Table 14. Correlation Test Results for Prioritization/Organizations/Networks.

Association Tested	Phi/Cramer's V	n	Significance
Use of prioritization schemes and the organization. (Companies, Military, Schools)	.27047	116	.01436
Use of prioritization schemes and the type of organization. (Military, Non-Military)	-.14859	116	.10952
Use of prioritization schemes and type of military installation. (Naval, Army, Air Force)	.21712	55	.27352
Use of prioritization schemes and the type of network architecture.	.09124	108	.92470

V. CONCLUSIONS AND RECOMMENDATIONS

A. CHARGEBACK

1. Adoption of Chargeback

Based on the survey responses, a majority of organizations are not using traditional forms of chargeback methodologies. Despite survey response instrument indications that 30% of organizations use chargeback, only one organization reported usage-based charging as a means to control bandwidth consumption. All other organizations, using chargeback mechanisms, focused on service-based rather than usage-based charging.

Service-based charging mechanisms accounted for virtually all forms of chargeback mechanisms reported. These charges related to network access. Charges to provide access to network resources accounted for 68% of all costs and flat rate fee structures accounted for a majority (63.3%) of all cost recovery methods. This illustrates that some network managers and administrators are concerned with growing IT costs, and that information technology is not free. However, it also illustrates that for the few network managers using chargeback, they are only attempting to recover network production costs through connection fees and capacity pricing and they are not trying to exert fine control over network resources or provide cost feedback to users of network resources.

User's of organizational networks are receiving little feedback on how they utilize network resources. Occasionally, if self-policing doesn't work, the users are notified to save large file transfers for night or weekends. Some network managers have reported that currently no policies are in place to assign additional costs to users or departments in the event that leased line capacities are exceeded. Instead these cost are to be absorbed at the organizational level. Some indicated that they simply monitor traffic patterns and congestion and increase bandwidth availability as needed.

Minimal user feedback for network costs, in combination with the notion that network resources are like utilities to be provided universally, has set the foundation for continued bandwidth expansion. "The solution is often wider arteries-as provided by technologies such as Fast Ethernet and Asynchronous Transfer Mode (ATM)-which can

carry data 10 or more times faster than conventional 10 Mbps Ethernet networks" (Henderson, 1997). The use of chargeback mechanisms as a method of resource management control and user feedback is not evident in the organizations surveyed. Instead organizations chose to improve bandwidth capacity.

Network managers provided several reasons why usage-based charging is not being employed. These reasons primarily included the complexity of determining, tracking, and eventually explaining to users the unit of incremental cost measurement. There were no reported standard units of measure by which incremental costs could be established. However, a tiered pricing structure, used in 6.1% of the cost recovery methods reported, was one effort by network managers to create some standard of incremental cost measure.

Eighty-five percent of all organizations surveyed indicated combination or non-homogenous network architectures which included multi-vendor and multi-protocol environments. These findings, combined with the single reported use of chargeback as a bandwidth control, support the idea in Chapter III, that chargeback for usage is too complex within distributed computing environments. Despite identifying several vendor software products available on the market today with accounting and chargeback functionalities, in addition to network traffic analysis capabilities, the organizations surveyed are not utilizing these products. These solutions are neither technically feasible nor are they practical for organizations with widely diversified network environments. Network managers realize no value-added potential from these tools.

Some have identified potential administrative overhead (time and effort to administer) as an unwanted or unneeded burden. In addition, considering that network managers are focusing on bandwidth solutions, they reported concern with bandwidth overhead or network capacity used by these products. One network manager reported, " if traffic congestion becomes a problem it is easier for me to purchase additional bandwidth capacity than to implement an elaborate chargeback system to control network access."

2. Future of Chargeback

The future of traditional usage-based chargeback methodologies will not take root within the increasingly complex distributed computing environment unless it can be implemented with minimal bandwidth and administrative overhead. This is unlikely due to

the inherent overhead associated with any usage-based accounting system that crosses organizational boundaries. Cultural barriers will also continue to exist within organizations as long as network access is treated like a utility. This research agrees with Drury's idea that support has become critical to users. "Many users tend to look at support as part of the package, essential to the infrastructure that IT is charged with supplying, rather than a charge which they should have to bear" (1997).

As WANs continue to expand, traffic monitoring tools will dominate accounting mechanisms on these infrastructures. The performance penalty and subsequent feedback to the network manager is too severe for WAN usage-based accounting to be considered. Traffic monitoring tools provide network managers with the ability to monitor network performance and take prompt corrective action if necessary. Consequently, the feedback they receive from the benefit of these tools is immediate.

As the rate of network complexity continues to change rapidly, network managers will focus on quality of service through additional performance monitoring techniques. They will add bandwidth capacity or focus on future technological solutions as the primary means of ensuring network performance. Fee structures in place at organizations are not functioning as chargeback management controls, but are merely providing capital for long-term continued infrastructure upgrades to support capacity planning and quality of service initiatives.

B. PRIORITIZATION

1. Adoption of Prioritization

Based on the survey responses, a majority of organizations are not using prioritization schemes. Only 15 out of 116 (12.9%) organizations reported the use of prioritization. But, of these responses, nine organizations indicated that bandwidth was prioritized by either data type or application. These findings, in conjunction with the extensive technological information about prioritization in Chapter II, provide significant support to many journalists' ideas regarding prioritization (Roberts, 1996), (Kalin, 1997), (Graziano, 1996), (Decisys, 1996), (Janah, 1996). They show that prioritization mechanisms are being used primarily for bandwidth management, although use of prioritization is not wide-spread.

Although there is not enough data to support a statistical difference, it is of interest to recognize that for the three companies reporting the use of prioritization, each indicated that they prioritized bandwidth. (Recall that only 12 companies were actually administered the survey.) This illustrates that for this small set of companies, they recognize the mission-critical importance of their networks and have taken steps in fortifying its position within their corporate strategy. They have established guidelines for policy-based traffic management within their organizations.

The cultural influences present within military installations and academic institutions may be hampering similar progress from occurring. The inherent bureaucracies that surround both academic and military installations make it easier to purchase additional bandwidth than to go through the administrative burden of establishing policy based management objectives. " Bandwidth has clearly been leading, but other things have been lacking ... [such as] policies and rules about the network, who can do what on the network and the flexibility of the network" (Kalin, 1997).

Although only 10 military installations reported use of prioritization, the Navy's ADNS research effort should not be overlooked. Despite the need for additional investigation into how mission needs affect ADNS prioritization policies, and whether routing priorities should be determined by application rather than by port only, ADNS is a significant cultural accomplishment by the Navy in recognizing the mission critical importance of its networks.

The confirmed existence of several bandwidth management controls based on prioritization and their confirmed use leads to the conclusion that the future of prioritization is much more certain than the future of chargeback as a bandwidth management control.

2. Future of Prioritization

There is no way around it–prioritation of network traffic is an inherent element of future network management. The proliferation of high bandwidth multimedia applications has eliminated any question concerning its use.

> If you had to boil down the entire data-networking business to just one line, it might be: Give me more-but only when I need it. That's because demand for bandwidth has never been greater, and it shows no signs of stopping (Janah, 1996).

Experts are arguing about what type of architecture will dominate future networks (ATM or Gigabit Ethernet), but none argue whether network traffic will require QoS or prioritization (Skorupa, 1997). The emergence of prioritization as a bandwidth management technique will require the attention and action of network managers.

C. RECOMMENDATIONS FOR DOD NETWORKS

> The balm for the bandwidth crunch, now and in the future, is to add more intelligence to networks. We have to create more intelligent networks that do more than just throw bandwidth at problems" (Kalin, 1997).

Although this quote could be simply an advertisement for 3Com's intelligent policy-based network products, this thesis has shown it to be a universal truth through the research findings. The Department of Defense must internalize this truth: digital bandwidth is a valuable electronic resource that is not a free good–it costs. This truth has been recognized by many commercial entities, and it deserves recognition in the Department of Defense as well. The sooner DOD network personnel are able to envision bandwidth as a economic resource, the better they will be at tracking their costs, utilizing resources, and optimizing their existing networks without resorting to costly upgrades and capital expenditures. IT may be a difficult area to manage, but the task will be much simpler once managers can identify their resources and prepare to manage them in an era of limited funding.

As stated before, the issue of usage-based chargeback in a distributed computing environment as a future bandwidth management technique is tenuous due to several obstacles. QoS and prioritization, on the other hand, are inevitable management practices if the DOD is to properly manage IT resources as mandated by the ITMRA. Given that 60% of organizations that are using prioritization are prioritizing bandwidth, and that many architectures and protocols that provide QoS are emerging, this shows that prioritization is arriving.

Immediate actions required by DOD agencies and installations include preparations for policy-based QoS and prioritization bandwidth management practices. It behooves each network manager to think *now* about potential policies for multimedia and to look at network usage, applications, and user groups. Develop a strategic plan to implement an organizational policy to use in the event bandwidth suddenly reaches maximum capacity. Prepare for the future.

This process should begin with examining what a priority scheme should be based on: users, their job titles or positions, their physical locations, specific applications, time of day the bandwidth is required, or others. These decisions must be made after gaining an in-depth knowledge of each type of user or user group.

This may require a survey of users in a medium to large organization (over 100 users) in order to properly categorize users and their requirements. Consideration must be given to future user requirements as well. Although some users may not require real-time, interactive network connections now, they may require it in the near future. Ask the users for their predictions of their future requirements, but don't assume that their "wish list" will be forthcoming.

The organization's or unit's mission and main functions should be examined in detail. Any elements of the mission that involve network usage must be listed and understood, and themselves be prioritized. This will provide a good basis on which to build a prioritization policy. Again, consideration must be given to future potential use of network resources to accomplish the mission, and must be included in a prioritization plan.

Once users and mission significance have been identified, the types of traffic used for each must be categorized. Each type of traffic has particular requirements, whether it is synchronous transmission and high bandwidth for voice and video data, or real-time transmission for a tracking system, or simple asynchronous packet transmission for ftp or email. These traffic types must also be identified and categorized.

All three of these criteria will allow development of a comprehensive prioritization scheme. If additional criteria are identified by the organization, they also should be included in determining priorities. One of the most important elements of creating this plan is to consider having clear value-added through the prioritization. Graziano supports this assertion in stating that a "clear business case for implementing policy-based management" is required (1996). An organization will want to plan prioritization for only what will need prioritization.

The prioritization plan should be developed with upper echelon levels of an organization, not simply the Information Systems, Information Management, or network management departments. If possible, it should also include second level functional area heads as well. A plan that has been agreed on before it is needed will be much better received once it has been implemented. A published plan will alleviate some of the problems associated with an abrupt change, and users will expect their traffic to be prioritized.

Even if prioritization is not and is not envisioned for your organization, this exercise will prepare you for any future contingencies. The reliance on networks by DOD is increasing, and should there be a large-scale conflict or war, the bandwidth demand will no doubt sky-rocket. Planning for prioritization of your network traffic will alleviate hasty or haphazard prioritization in the future, when QoS applications will be required to make decisions. A prioritization plan will prepare an organization to use QoS or class-of-service technologies when they become available (McLean, 1997).

A logical extension of traffic policy management may be chargeback for usage, as bandwidth management becomes more common, and resource control becomes more important. Along with developing prioritization policies, managers could use chargeback for bandwidth utilization. Our research finding that most organizations charged users for access to networks supports this idea, also presented by Stephenson (1997) and McLean (1997). Reliance on the Internet to establish standard practice is obvious, as organizations are charging a flat fee or tiered fee for user access, just like Internet Service Providers (ISPs) are. As ISPs are developing techniques to bill users for usage (d-Comm, 1997), organizations will also begin to chargeback for usage.

DOD organizations must also become familiar with emerging QoS technologies, and stay current on them. Although a particular service may be pushing to install a specific architecture, like the Navy's current IT-21 initiative which directs installation of ATM, network managers may end up losing if they don't stay on top of these emerging technologies. The war between Fast Ethernet, Gigabit Ethernet, and ATM is still raging, and none of these architectures has met all the internetworking needs of organizations. In order to avoid the pitfalls of making wrong architecture choices, network managers must keep abreast of all developments regarding QoS and traffic prioritization–whether it's standardized or not. All proprietary architectures have potential to become open or simply adopted as de facto standards. In addition, a particular architecture could be the ideal solution for an organization, but it may be missed if network managers are not looking.

Specific frontier technology architectures and protocols to monitor include:

- RSVP. This protocol has a tremendous potential to provide multimedia QoS to all network architectures it is used with.
- 802.1p and 802.1q. As Gigabit Ethernet is developed (expected to be standardized in 1998), it may not only provide an expanded bandwidth, but along with these standards, it may provide a needed networking solution. As

with any network architecture of the future, "prioritization is a big concern" (Roberts, 1997a).

- Policy servers. These may not evolve strictly as a "policy server" (Bruno, 1997), but some form of centralized policy management repository will evolve, and DOD needs corporate knowledge on them as another solution.

Once all these steps are taken by the DOD organization, it will be well prepared to manage its 21st Century network as it provides information superiority demanded by Joint Vision 2010.

> Sustaining the responsive, high quality data processing and information needed for joint military operation will require more than just an edge over an adversary. We must have information superiority: the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same (CJCS, 1996).

This uninterrupted flow of information can be obtained using communication pipes with controlled congestion. With effective bandwidth management practices like prioritization and chargeback, DOD network managers can "achieve the tradeoffs that will bring the best balance, most capability, and greatest interoperability for the least cost" (CJCS, 1996).

D. SUGGESTED FURTHER STUDIES

This exploratory study has only begun to uncover the growing body of knowledge on policy-based management, chargeback, QoS, and prioritization. There is a wealth of potential topics that warrant further study. A few are listed below:

•Corporate bandwidth management practices. If DOD is treating the military as a business (ITMRA mandated), more data is needed on how they are managing bandwidth.

•Identify 2-3 specific corporate entities who are using chargeback or prioritization, and do case studies. Find detailed practices that are applicable for DOD or specific command's usage.

•Identify a specific product, methodology, or architecture and analyze its potential for DOD or a specific service.

•Identify 2-3 specific products and analyze their potential for a single command or installation.

•Complete an in-depth taxonomy of products as they develop. (Products that are available today may be outdone by products of tomorrow.)

•Once RSVP is standardized and implemented, study its effects on network management and network usage.

•Compare ATM solutions to Gigabit Ethernet solutions once Gigabit Ethernet is standardized.

•What is the economic feasibility of installing and using these tools? Conduct a cost/benefit analysis for a single organization.

•Are ADNS concepts (mobile IP communications) adaptable by sister services/ DOD-wide?

APPENDIX A. SURVEY INSTRUMENT

Copies of correspondence to organization webmasters, and to targeted network personnel are included to document how they were approached. As stated earlier, initially email was sent to webmasters in an attempt to find network personnel (the first email document). If a contact was given, then a copy of the survey instrument was sent (the second email document).

To: webmaster@organization.com
From: "Kristine M. Davis" <krisdavis@sprynet.com>
Subject: Website Feedback—>Looking for LAN/WAN Management Point of Contact

Dear Webmaster/Staff,

Hi! I've been surfing the Internet as part of my research, and I really like your web site! Unfortunately, I haven't found exactly what I'm looking for. I am a student in Information Technology Management at the Naval Postgraduate School in Monterey, CA. I am doing research on digital computer networks used by corporate, academic, and military organizations. Specifically, I am researching use of PRIORITIZATION AND/OR CHARGEBACK MECHANISMS TO MANAGE NETWORK USAGE, and I'd like to include your organization.
I am trying to get in touch with someone on your LAN/WAN management team to do my research, but can't find specific information I need on your site. Would it be possible to obtain the name, phone number and e-mail address of someone on the network management team? (E-mail address would be preferred.)
Any information you can provide to point me in the right direction would be greatly appreciated.

THANK YOU FOR YOUR TIME AND EFFORT!

Sincerely, K. M. Davis, LT, U.S. Navy

To: dmjones@nowhere.usa
From: "Kristine M. Davis" <krisdavis@sprynet.com>
Subject: QUESTIONS ABOUT NETWORK MANAGEMENT

Dear Mr. Jones,

Thank you for your time and effort to respond to my query. I am conducting research for my master's thesis, and I hope you can help me with my research. Here's a rundown on what I'm researching...
****

The following questions are intended to assist in graduate research in the Information Technology Management field. I am a student at the Naval Postgraduate School and I'm researching the use of prioritization(policy-based management) and/or chargeback mechanisms as a way of managing network bandwidth (considering it as a scarce resource).

I will appreciate if you can take a few minutes to respond to the following 4 questions via e-mail.

1. How would you classify your organization's LAN/WAN network? (ATM, Ethernet, Fast Ethernet, FDDI, or combination–PLEASE CLARIFY IF COMBINATION)

2. Does your organization prioritize network traffic and/or network access?

3. If so, how is it prioritized? (By application, user, data origin, data destination, first come-first served, IP address, etc.)

PLEASE DESCRIBE.

4. Does your organization charge users for network resources? (By time, transaction, application, network connection, connection speed, etc.)

PLEASE DESCRIBE.

Please respond by a return e-mail. If you have any questions
concerning this, please feel free to email me or to call.

****

THANK YOU FOR YOUR TIME AND YOUR WILLINGNESS TO SHARE YOUR EXPERTISE!!!

****

Very Respectfully,
K. M. Davis, LT, U.S. Navy

****

kmdavis@nps.navy.mil	407P Tyler Place
krisdavis@m9.sprynet.com	Salinas, CA 93906
Voicemail: (408) 656-2536 X2494	Home: (408)444-6454

****

APPENDIX B. BINOMIAL TEST RESULTS

This appendix contains data printouts from SPSS statistical package version 6.1.2. The printouts include binomial test results for all descriptive hypotheses tested. Binomial non-parametric statistical tests were performed since the samples obtained were non-probabilistic and each case was treated as a single sample. These are provided as documentation.

H: 51% of all orgs use prioritization

PRIORITY Prioritization

Cases

		Test Prop. = .5100
15	= 1	Obs. Prop. = .1293
101	= 0	
---		Z Approximation
116	Total	1-Tailed P = .0000-Reject the null hypothesis

CHARGEBK Chargeback

H: 51% of all orgs use chargeback

Cases

		Test Prop. = .5100
36	= 1	Obs. Prop. = .3000
84	= 0	
---		Z Approximation
120	Total	1-Tailed P = .0000-Reject the null hypothesis

PRIORITY Prioritization

H: 51% of Military orgs use prioritization

Cases

Test Prop. = .5100
10 = 1 Obs. Prop. = .1818
45 = 0
-- Z Approximation
55 Total 1-Tailed P = .0000-Reject the null hypothesis

CHARGEBK Chargeback
H: 51% of Military orgs use chargeback
Cases
Test Prop. = .5100
6 = 1 Obs. Prop. = .1053
51 = 0
-- Z Approximation
57 Total 1-Tailed P = .0000-Reject the null hypothesis

PRIORITY Prioritization
H: 51% of commercial orgs use prioritization

Cases
Test Prop. = .5100
3 = 1 Obs. Prop. = .3333
6 = 0
-- Exact Binomial
9 Total 1-Tailed P = .2346-Failed to reject the null hypothesis

---

CHARGEBK Chargeback
H: 51% of commercial orgs use chargeback
Cases
Test Prop. = .5100
6 = 1 Obs. Prop. = .5455
5 = 0

--		Exact Binomial	
11	Total	1-Tailed P =	.5271-Failed to reject the null hypothesis

----

PRIORITY Prioritization

H: 51% of academic orgs use prioritization

Cases			
		Test Prop. =	.5100
2	= 1	Obs. Prop. =	.0385
50	= 0		
--		Z Approximation	
52	Total	1-Tailed P =	.0000-Reject the null hypothesis

CHARGEBK Chargeback

H: 51% of academic orgs use chargeback

Cases			
		Test Prop. =	.5100
24	= 1	Obs. Prop. =	.4615
28	= 0		
--		Z Approximation	
52	Total	1-Tailed P =	.2876-Failed to reject the null hypothesis

APPENDIX C. CHI-SQUARED TEST RESULTS

This appendix contains data printouts from SPSS statistical package version 6.1.2. The printouts include chi-squared test results for all relational hypotheses tested. It is organized by organization tests and network tests. Chi-squared non-parametric statistical tests were used since the samples obtained were non-probabilistic, data was nominal, and segmentation of the data allowed for analysis of the data as multiple sample cases. Expected values used in chi-squared tests are based on percentages equivalent to the response rates received from each organization. This was necessary due to the differing number of responses received from each organization.

ORGANIZATION TESTS

-- Chi-Square Test

Selected all organizations that use Chargeback.

Expected values agree in ratio with response percentages received.

H: Use of chargeback is independent of class

CLASS CLASSIFICATION

	Cases			
	Category	Observed	Expected	Residual
COMPANY	1	6	3.56	2.44
MILITARY	2	6	16.96	-10.96
SCHOOL	3	24	15.48	8.52
		--		
	Total	36		

Warning - Chi-Square statistic is questionable here.

1 cells have expected frequencies less than 5.

Minimum expected cell frequency is 3.6

Chi-Square	D.F.	Significance
13.4335	2	.0012

-- Chi-Square Test

Selected all organizations that DO NOT use Chargeback.

Expected values agree in ratio with response percentages received.

H: Non-Use of chargeback is independent of class

CLASS CLASSIFICATION

	Cases			
	Category	Observed	Expected	Residual
COMPANY	1	5	8.32	-3.32
MILITARY	2	51	39.56	11.44
SCHOOL	3	28	36.12	-8.12
	--			
	Total	84		

Chi-Square	D.F.	Significance
6.4533	2	.0397

Critical value for 2 D.F. is 5.99 (Sig. Level=.05),

Chi-square (13.4)>5.99, =>reject null hypothesis

-- Chi-Square Test

Selected all organizations that use Prioritization.

Expected values agree in ratio with response percentages received.

H: Use of Prioritization is independent of class

CLASS CLASSIFICATION

	Cases			
	Category	Observed	Expected	Residual
COMPANY	1	3	1.49	1.51
MILITARY	2	10	7.06	2.94
SCHOOL	3	2	6.45	-4.45
	--			
	Total	15		

Warning - Chi-Square statistic is questionable here.
1 cells have expected frequencies less than 5.
Minimum expected cell frequency is 1.5

Chi-Square	D.F.	Significance
5.8350	2	.0541

-- Chi-Square Test

Selected all organizations that DO NOT use Prioritization.

Expected values agree in ratio with response percentages received.

H: Non-Use of Prioritization is independent of class

CLASS CLASSIFICATION

	Category	Cases Observed	Expected	Residual
COMPANY	1	6	10.00	-4.00
MILITARY	2	45	47.57	-2.57
SCHOOL	3	50	43.43	6.57

	Total	101		

Chi-Square	D.F.	Significance
2.7322	2	.2551

Critical value for 2 D.F. is 5.99 (Sig. Level=.05),

Chi-square (2.7)<5.99, =>fail to reject null hypothesis

-- Chi-Square Test

Selected all organizations that use Chargeback.

Expected values agree in ratio with response percentages received.

H: Use of Chargeback is independent of the type of org (Military vs Non)

TYPEORG Type of Organization

	Cases			
	Category	Observed	Expected	Residual
Military	1	6	16.96	-10.96
Non-military	2	30	19.04	10.96
	--			
	Total	36		

Chi-Square	D.F.	Significance
13.3821	1	.0003

Critical value for 2 D.F. is 5.99 (Sig. Level=.05),

Chi-square (13.4)>5.99, =>reject null hypothesis

-- Chi-Square Test

Selected all organizations that use Prioritization.

Expected values agree in ratio with response percentages received.

H: Use of Prioritization is independent of type of org (Military, Non)

TYPEORG Type of Organization

	Cases			
	Category	Observed	Expected	Residual
Military	1	10	7.06	2.94
Non-military	2	5	7.93	-2.93
	--			
	Total	15		

Chi-Square	D.F.	Significance
2.3049	1	.1290

Critical value for 1 D.F. is 3.84 (Sig. Level=.05),
Chi-square (2.3)< 3.84=>fail to reject null hypothesis

--- Chi-Square Test

Selected Military organizations that use Chargeback.
Expected values agree in ratio with response percentages received.

H: Use of Chargeback is independent of Military Service (Naval, Army, Air Force)

ORGNZTN Organization Surveyed

		Cases		
	Category	Observed	Expected	Residual
Naval	2	1	1.79	-.79
Army	4	2	1.05	.95
Air Force	5	3	3.16	-.16
		-		
	Total	6		

Warning - Chi-Square statistic is questionable here.
3 cells have expected frequencies less than 5.
Minimum expected cell frequency is 1.1

Chi-Square	D.F.	Significance
1.2133	2	.5452

--- Chi-Square Test

Selected Military organizations that DO NOT use Chargeback.
Expected values agree in ratio with response percentages received.

H: Non-Use of Chargeback is independent of Military Service
(Naval, Army, Air Force)

ORGNZTN Organization Surveyed

	Cases			
	Category	Observed	Expected	Residual
Naval	2	16	15.21	.79
Army	4	8	8.93	-.93
Air Force	5	27	26.85	.15
		--		
	Total	51		

Chi-Square	D.F.	Significance
.1391	2	.9328

Critical value for 2 D.F. is 5.99 (Sig. Level=.05),
Chi-square (.14)< 5.99=>fail to reject null hypothesis

-- Chi-Square Test

Selected Military organizations that use Priority.
Expected values agree in ratio with response percentages received.

H: Use of Prioritization is independent of Military Service
(Naval, Army, Air Force)
ORGNZTN Organization Surveyed

	Cases			
	Category	Observed	Expected	Residual
Naval	2	1	2.98	-1.98
Army	4	3	1.75	1.25
Air Force	5	6	5.27	.73
		--		
	Total	10		

Warning - Chi-Square statistic is questionable here.
2 cells have expected frequencies less than 5.
Minimum expected cell frequency is 1.8

Chi-Square	D.F.	Significance
2.3102	2	.3150

---Chi-Square Test

Selected Military organizations that DO NOT use Priority.
Expected values agree in ratio with response percentages received.

H: Non-Use of Prioritization is independent of Military Service
(Naval, Army, Air Force)
ORGNZTN Organization Surveyed

	Category	Cases Observed	Expected	Residual
Naval	2	15	13.42	1.58
Army	4	7	7.88	-.88
Air Force	5	23	23.69	-.69
		--		
	Total	45		

Chi-Square	D.F.	Significance
.3044	2	.8588

Critical value for 2 D.F. is 5.99 (Sig. Level=.05),
Chi-square (.3)< 5.99=>fail to reject null hypothesis

NETWORK TESTS

--- Chi-Square Test

H: USE OF CHARGEBACK IS INDEPENDENT OF NETWORK TYPE
(USERS OF CHARGEBACK)
TYPENET Type Network

	Category	Cases Observed	Expected	Residual
combination	1	32	11.33	20.67
ethernet	2	1	11.33	-10.33
fast ethernet	3	1	11.33	-10.33
	--			
Total		34		

Chi-Square	D.F.	Significance
56.5294	2	.0000

CRITICAL VALUE FOR 2 D.F. IS 5.99 (SIG LEVEL=.05),
CHI-SQUARED (56.5)> 5.99, SO REJECT NULL HYPOTHESIS

--- Chi-Square Test

H: USE OF PRIORITIZATION IS INDEPENDENT OF NETWORK TYPE
(USERS OF PRIORITY)
TYPENET Type Network

	Category	Cases Observed	Expected	Residual
combination	1	14	7.50	6.50
ethernet	2	1	7.50	-6.50
	--			
Total		15		

Chi-Square	D.F.	Significance
11.2667	1	.0008

CRITICAL VALUE FOR 1 D.F. IS 3.84 (SIG LEVEL=.05),
CHI-SQUARED (11.2)> 3.84, SO REJECT NULL HYPOTHESIS

---Chi-Square Test

H: USE OF CHARGEBACK IS INDEPENDENT OF NETWORK TYPE FOR:
(COMPANIES WHO USE CHARGEBACK)
TYPENET Type Network

		Cases		
	Category	Observed	Expected	Residual
combination	1	5	5.00	.00
	-			
	Total	5		

Only one cell generated. Test abandoned.

--- Chi-Square Test

H: USE OF CHARGEBACK IS INDEPENDENT OF NETWORK TYPE FOR:
(MILITARY WHO USE CHARGEBACK)
TYPENET Type Network

		Cases		
	Category	Observed	Expected	Residual
combination	1	5	5.00	.00
	-			
	Total	5		

Only one cell generated. Test abandoned.

-- Chi-Square Test

H: USE OF CHARGEBACK IS INDEPENDENT OF NETWORK TYPE FOR:
(SCHOOLS WHO USE CHARGEBACK)
TYPENET Type Network

	Category	Cases Observed	Expected	Residual
combination	1	21	7.67	13.33
ethernet	2	1	7.67	-6.67
fast ethernet	3	1	7.67	-6.67
	--			
	Total	23		

Chi-Square	D.F.	Significance
34.7826	2	.0000

CRITICAL VALUE FOR 2 D.F. IS 5.99 (SIG LEVEL=.05),
CHI-SQUARED (34.8)> 5.99, SO REJECT NULL HYPOTHESIS

--Chi-Square Test

H: USE OF PRIORITIZATION IS INDEPENDENT OF NETWORK TYPE
(COMPANIES THAT USE PRIORITIZATION)
TYPENET Type Network

	Category	Cases Observed	Expected	Residual
combination	1	3	3.00	.00
	-			
	Total	3		

Only one cell generated. Test abandoned.

---Chi-Square Test

H: USE OF PRIORITIZATION IS INDEPENDENT OF NETWORK TYPE (MILITARY THAT USE PRIORITIZATION)

Not enough cases for processing

--- Chi-Square Test

H: USE OF PRIORITIZATION IS INDEPENDENT OF NETWORK TYPE (SCHOOLS THAT USE PRIORITIZATION)

TYPENET Type Network

	Category	Cases Observed	Expected	Residual
combination	1	2	2.00	.00
	Total	2		

Only one cell generated. Test abandoned.

---Chi-Square Test

H: USE OF CHARGEBACK IS INDEPENDENT OF NETWORK TYPE (NON-MILITARY THAT USE CHARGEBACK)

TYPENET Type Network

	Category	Cases Observed	Expected	Residual
combination	1	26	9.33	16.67
ethernet	2	1	9.33	-8.33
fast ethernet	3	1	9.33	-8.33
	Total	28		

Chi-Square	D.F.	Significance
44.6429	2	.0000

CRITICAL VALUE FOR 2 D.F. IS 5.99 (SIG LEVEL=.05),
CHI-SQUARED (44.6)> 5.99, SO REJECT NULL HYPOTHESIS

-- Chi-Square Test

H: USE OF PRIORITIZAION IS INDEPENDENT OF NETWORK TYPE
(NON-MILITARY THAT USE PRIORITIZATION)

TYPENET Type Network

	Category	Cases Observed	Expected	Residual
combination	1	5	5.00	.00
	Total	5		

Only one cell generated. Test abandoned.

--Chi-Square Test

Selected if(typenet = 2 OR subtypea =1 OR subtypeb = 1
OR subtypec = 1 OR subtyped=1 OR subtypee=1
OR subtypef=1) AND chargebk=1
(i.e. All orgs that use chargeback that have ethernet)
Expected values agree in ratio with response percentages received.
Test is 1 sample chi-squared test.

H: USE OF CHARGEBACK IS INDEPENDENT OF ORGANIZATIONS THAT USE ETHERNET

CLASS CLASSIFICATION

	Category	Cases Observed	Expected	Residual
COMPANY	1	5	3.27	1.73
MILITARY	2	6	15.54	-9.54

SCHOOL	3	22	14.19	7.81
	--			
Total	33			

Warning - Chi-Square statistic is questionable here.
1 cells have expected frequencies less than 5.
Minimum expected cell frequency is 3.3

Chi-Square	D.F.	Significance
11.0770	2	.0039

-- Chi-Square Test

Selected if(typenet = 2 OR subtypea =1 OR subtypeb = 1
OR subtypec = 1 OR subtyped=1 OR subtypee=1
OR subtypef=1) AND chargebk=0
(i.e. All orgs that DO NOT use chargeback that have ethernet)
Expected values agree in ratio with response percentages received.
Test is 1 sample chi-squared test.

H: NON-USE OF CHARGEBACK IS INDEPENDENT OF ORGANIZATIONS THAT USE ETHERNET

CLASS CLASSIFICATION

	Cases			
	Category	Observed	Expected	Residual
COMPANY	1	3	7.13	-4.13
MILITARY	2	44	33.91	10.09
SCHOOL	3	25	30.96	-5.96
	--			
	Total	72		

Chi-Square	D.F.	Significance
6.5389	2	.0380

CRITICAL VALUE FOR 2 D.F. IS 5.99 (SIG LEVEL=.05),
CHI-SQUARED (6.5)> 5.99, SO REJECT NULL HYPOTHESIS

---Chi-Square Test
Selected if(typenet = 3 OR subtypea =2 OR subtypeb = 2
OR subtypec = 2 OR subtyped=2 OR subtypee=2
OR subtypef=2) AND chargebk=1
(i.e. All orgs that use chargeback that have fast ethernet)
Expected values agree in ratio with response percentages received.
Test is 1 sample chi-squared test.

H: USE OF CHARGEBACK IS INDEPENDENT OF ORGANIZATIONS THAT USE FAST ETHERNET

CLASS CLASSIFICATION

	Category	Cases Observed	Expected	Residual
COMPANY	1	4	2.57	1.43
MILITARY	2	4	12.25	-8.25
SCHOOL	3	18	11.18	6.82
		--		
	Total	26		

Warning - Chi-Square statistic is questionable here.
1 cells have expected frequencies less than 5.
Minimum expected cell frequency is 2.6

Chi-Square	D.F.	Significance
10.5029	2	.0052

- - - - - Chi-Square Test
Selected if(typenet = 3 OR subtypea =2 OR subtypeb = 2
OR subtypec = 2 OR subtyped=2 OR subtypee=2

OR subtypef=2) AND chargebk=0
(i.e. All orgs that DO NOT use chargeback that have fast ethernet)
Expected values agree in ratio with response percentages received.
Test is 1 sample chi-squared test.

H: NON-USE OF CHARGEBACK IS INDEPENDENT OF ORGANIZATIONS THAT USE FAST ETHERNET

CLASS CLASSIFICATION

	Category	Cases Observed	Expected	Residual
COMPANY	1	2	3.07	-1.07
MILITARY	2	16	14.60	1.40
SCHOOL	3	13	13.33	-.33
	--			
Total		31		

Warning - Chi-Square statistic is questionable here.
1 cells have expected frequencies less than 5.
Minimum expected cell frequency is 3.1

Chi-Square	D.F.	Significance
.5146	2	.7731

-- Chi-Square Test
Selected if(typenet = 4 OR subtypea =3 OR subtypeb = 3
OR subtypec = 3 OR subtyped=3 OR subtypee=3
OR subtypef=3) AND chargebk=1
(i.e. All orgs that use chargeback that have FDDI)
Expected values agree in ratio with response percentages received.
Test is 1 sample chi-squared test.

H: USE OF CHARGEBACK IS INDEPENDENT OF ORGANIZATIONS THAT USE FDDI

CLASS CLASSIFICATION

	Category	Cases Observed	Expected	Residual
COMPANY	1	2	1.19	.81
MILITARY	2	2	5.65	-3.65
SCHOOL	3	8	5.16	2.84
		--		
	Total	12		

Warning - Chi-Square statistic is questionable here.
1 cells have expected frequencies less than 5.
Minimum expected cell frequency is 1.2

Chi-Square	D.F.	Significance
4.4778	2	.1066

---Chi-Square Test

Selected if(typenet = 4 OR subtypea =3 OR subtypeb = 3
OR subtypec = 3 OR subtyped=3 OR subtypee=3
OR subtypef=3) AND chargebk=0
(i.e. All orgs that DO NOT use chargeback that have FDDI)
Expected values agree in ratio with response percentages received.
Test is 1 sample chi-squared test.

H: NON-USE OF CHARGEBACK IS INDEPENDENT OF ORGANIZATIONS THAT USE FDDI

CLASS CLASSIFICATION

Category	Cases Observed	Expected	Residual

COMPANY	1	1	1.19	-.19
MILITARY	2	5	5.65	-.65
SCHOOL	3	6	5.16	.84
		--		
	Total	12		

Warning - Chi-Square statistic is questionable here.
1 cells have expected frequencies less than 5.
Minimum expected cell frequency is 1.2

Chi-Square	D.F.	Significance
.2417	2	.8862

APPENDIX D. CORRELATION RESULTS

This appendix contains data printouts from SPSS statistical package version 6.1.2. The printouts include cross tabulation correlation test results for all correlations tested. Cross tabulation non-parametric statistical tests were used since the data obtained was nominal. Phi and Cramer's V measures of correlation were determined due to the non-probabilistic nature of the data.

---Cross Tabulation

CLASS CLASSIFICATION by CHARGEBK

Count

		No 0	Yes 1	Row Total
CLASS				
	1	5	6	11
COMPANY				9.2
	2	51	6	57
MILITARY				47.5
	3	28	24	52
SCHOOL				43.3
	Column	84		
36 120				
	Total	70.0	30.0	100.0

Approximate Statistic	Value	Significance
Phi	.40733	.00005
Cramer's V	.40733	.00005

Number of Missing Observations: 1

---Cross Tabulation

TYPEORG Type of Organization by CHARGEBK
CHARGEBK

Count

		No 0	Yes 1	Row Total
TYPEORG				
	1	51	6	57
Military				47.5
	2	33	30	63

Non-military				52.5
	Column	84	36	120
	Total	70.0	30.0	100.0

Approximate Statistic	Value	Significance
Phi	.40421	.00001
Cramer's V	.40421	.00001

Number of Missing Observations: 1

---Cross Tabulation

ORGNZTN Organization Surveyed by CHARGEBK

		Count No 0	Yes 1	Row Total
ORGNZTN				
	2	16	1	17
Naval				29.8
	4	8	2	10
Army				17.5
	5	27	3	30
Air Force				52.6
	Column	51	6	57
	Total	89.5	10.5	100.0

Approximate Statistic	Value	Significance
Phi	.15396	.50889
Cramer's V	.15396	.50889

Number of Missing Observations: 0

---Cross Tabulation

CLASS CLASSIFICATION by PRIORITY

		Count No 0	Yes 1	Row Total
CLASS				
	1	6	3	9
COMPANY				7.8
	2	45	10	55
MILITARY				47.4
	3	50	2	52
SCHOOL				44.8

	Column	101	15	116
	Total	87.1	12.9	100.0

Approximate Statistic	Value	Significance
Phi	.27047	.01436
Cramer's V	.27047	.01436

Number of Missing Observations: 5

---Cross Tabulation

TYPEORG Type of Organization by PRIORITY

		Count No 0	Yes 1	Row Total
TYPEORG				
Military	1	45	10	55 47.4
Non-military	2	56	5	61 52.6
	Column Total	101 87.1	15 12.9	116 100.0

Approximate Statistic	Value	Significance
Phi	-.14859	.10952
Cramer's V	.14859	
.10952		

Number of Missing Observations: 5

---Cross Tabulation

ORGNZTN Organization Surveyed by PRIORITY

		Count No 0	Yes 1	Row Total
ORGNZTN				
Naval	2	15	1	16 29.1
Army	4	7	3	10 18.2
Air Force	5	23	6	29 52.7
	Column Total	45 81.8	10 18.2	55 100.0

Approximate Statistic	Value	Significance
Phi	.21712	.27352

Cramer's V	.21712	.27352

Number of Missing Observations: 2

--Cross Tabulation

Type Network by PRIORITY Prioritization

PRIORITY Count		No 0	Yes 1	Row Total
TYPENET				
	1	79	14	93
combination				86.1
	2	11	1	12
ethernet				11.1
	3	1		1
fast ethernet				.9
	4	1		1
FDDI				.9
	6	1		1
token ring				.9
Column Total		93	15	108
		86.1	13.9	100.0

Approximate Statistic	Value	Significance
Phi	.09124	.92470
Cramer's V	.09124	.92470

Number of Missing Observations: 13

--Cross Tabulation

TYPENET Type Network by CHARGEBK Chargeback

CHARGEBK

Count		No 0	Yes 1	Row Total
TYPENET				
	1	61	32	93
combination				85.3
	2	12	1	13
ethernet				11.9
	3	1		1
fast ethernet				.9
	4	1		1
FDDI				.9
	6	1		1
token ring				.9
Column		75	34	109
Total		68.8	31.2	100.0

Approximate Statistic	Value	Significance
Phi	.25171	.14095
Cramer's V	.25171	.14095

Number of Missing Observations: 12

--Cross Tabulation

TYPENET Type Network by CLASS CLASSIFICATION

CLASS Count		COMPANY 1	MILITARY 2	SCHOOL 3	Row Total
TYPENET					
	1	7	45	41	93
combination					85.3
	2	1	6	6	13
ethernet					11.9

COMPANY MILITARY SCHOOL

		1	2	3	Row Total
TYPENET					
	1	7	45	41	93
combination					85.3
	2	1	6	6	13
ethernet					11.9
	3			1	1
fast ethernet					.9
	4		1		1
FDDI					.9
	6		1		1
token ring					.9
	Column	8	53	48	109
	Total	7.3	48.6	44.0	100.0

Approximate Statistic	Value	Significance
Phi	.17717	.90521
Cramer's V	.12528	.90521

Number of Missing Observations: 12

- -

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